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CHAPTER 6

PERCEPTUAL-MOTOR CHARACTERISTICS

6.1 INTRODUCTION

In comparison to physical characteristics, the relationship between perceptual-motor variables and sporting success is less well understood. Only a limited number of studies have examined the relationship between perceptual-motor variables and gymnastic performance (Jancarik & Salmela, 1987; Régnier & Salmela, 1987; Sol, 1987). However, the research associated with the Canadian Testing for National Talent Programme highlighted the important contribution of perceptual-motor variables in explaining variance in the competitive performance of male gymnasts. When expressed in terms of the percentage of variance explained by the first two variables in each selected dimension, perceptual-motor characteristics explained the largest proportion of variance in competitive performance in four out of the six age groups studied. However, the contribution of perceptual-motor variables in terms of unique variance was not estimated and therefore this study provides only preliminary support for the importance of perceptual-motor variables. This chapter will examine the relationship between selected perceptual-motor characteristics and future gymnastic performance using the statistical techniques of principal components analysis and logistic regression. Variables from the following categories were identified as potentially prognostic indicators of gymnastic talent and included in the analysis: postural sway, balance, kinaesthesis and electromechanical response times. In addition, the stability and longitudinal development of the selected perceptual-motor characteristics will be examined using rank order autocorrelations.

Only a limited number of studies have examined the differences between perceptual-motor characteristics in groups of gymnasts and controls and/or have investigated the longitudinal development of these variables (Jancarik & Salmela, 1987; Régnier & Salmela, 1987; Sol, 1987; Claessens et al., 1998; Kioumoutzoglou et al., 1998). The apparent lack of research interest may be the result of the difficulties associated with producing accurate and reliable measures of perceptual-motor characteristics in field conditions. For example, the measurement of perceptual-motor characteristics has been associated with large

variances and poor reliability (Jancarik & Salmela, 1987). However, as stated by Helmstadter (1964), the limitations associated with the measurement of perceptual-motor characteristics do not provide justification for such variables to be excluded:

> "In some instances a reliability which is far from perfect may be the best yet, or much better than impressionistic judgement, or simply ignoring the trait because no measurement device is available"
>
> (Helmstadter, 1964 op cit. Laszlo & Bairstow, 1985a)

Therefore, in the current investigation the threshold level required to conclude adequate reliability was relaxed for perceptual-motor variables to reflect the nature of the data within this dimension.

6.2 REVIEW OF LITERATURE

6.2.1 POSTURAL SWAY

Quiet standing is a dynamic situation which involves the maintenance of an unstable equilibrium. The goal of postural control during upright stance is to preserve this equilibrium by maintaining the horizontal position of the body's mass centre (CM) over the base of support through the appropriate application of muscular torques (Hageman, Leibowitz, & Blanke, 1995; Panzer, Bandinelli & Hallett, 1995; Hayes, 1982). Attempts by an individual to stand motionless are characterised by micro movements upon a stationary base (Hellebrandt, 1938), these movements are referred to as postural sway. Several reasons have been postulated to explain the physiological utility of postural sway, most frequently cited is its role in the prevention of orthostatic circulatory insufficiency/venous pooling (Hellebrandt, 1938 op cit. Murray, Seireg & Sepic, 1975). Postural sway has traditionally been investigated in the ageing or elderly population or in subjects with neurological disease (Lucy & Hayes, 1985). However, a number of studies have examined the development of postural stability within the growing child, with particular emphasis upon the development of postural control in the period of transition to an upright posture (Woollacott, Dêbu & Shumway-Cook, 1987).

Previous investigations have examined postural sway from two approaches; steadiness and stability. Steadiness relates to the control of posture during quiet stance, while stability pertains to the responses of the postural system to perturbations. There has been limited research focusing on the potential importance of postural steadiness in the sporting population. Studies involving target sports requiring a high degree of accuracy such as rifle shooting are the most notable exceptions (Era, Konttinen, Mehto, Saarda & Lyytinen, 1996; Niinimaa & McAvoy, 1983 op cit. Lees, 1986a). The majority of sporting investigations have been concerned with the relationship between postural sway, injury prevention and rehabilitation (Jones, 1991; Irrgang, Whitney & Cox, 1994; Goldie, Evans & Bach, 1992; Tropp, Ekstrand & Gillquist, 1984).

The importance of steadiness and moreover dynamic stability in Women's Artistic Gymnastics is self-evident given the sport's requirements for precision and control, most notably with regard to performance on the balance beam. While studies have investigated the mechanisms through which postural steadiness can be maintained during bilateral and inverted stances (Slobounov & Newell, 1996) there has been no research to determine the validity of postural sway in the context of performance prediction in dynamic sports such as gymnastics. Studies comparing postural stability between gymnasts and a control population have considered age and moreover the duration of gymnastic experience as important variables (Debu, Woollacott & Mowatt, 1988; Debu & Woollacott, 1988; Pedotti, Crenna, Deat, Frigo & Massion, 1989 op cit. Foster, Sveistrup & Woollacott, 1996). Whilst these studies have provided an insight into the nature and function of stability in a sample of experienced gymnasts, investigations have been predominantly cross-sectional and have failed to unequivocally determine the degree to which postural stability is innate or may be developed through gymnastic training and experience.

Techniques of investigation

Biological and neurophysiological perspectives have been adopted in the investigation of postural sway. The perspective adopted influences both the method of data collection and the subsequent analysis. The various techniques applied to record postural sway can be grouped according to a tripartite classification (Murray et al., 1975; Hasan, Lichtenstein, & Shiavi, 1990; Maki, 1986);

i. measurement of body segment displacement

ii. measurement of muscle activity

iii. movement of COP using platform stabilometry

With respect to measures of body segment displacement, early investigations involved the fixation of markers to the head or shoulders of the subject to enable the path of lateral sway to be transcribed onto paper (Sheldon, 1963 op cit. Fitzgerald, Murray, Elliot, & Burchall, 1993). Accelerometers and potentiometers have also been employed to investigate the sway of various body segments (Thomas & Whitney, 1959; Shumway-Cook & Woollacott, 1985). More recently, the method of sway magnetometry was introduced by Dean, Griffiths & Murray (1986). A transmitter coil produced a magnetic field that was detected by two receiver coils worn around the subject's waist. The strength of the magnetic field was used to determine the distance between the two coils and the associated movement of the hips. The positioning of the two receiver coils enabled two-dimensional hip movements in both sagittal and coronal planes to be recorded. More recently, light sources (optoelectric devices) have been employed to record sway and detect movements of the mass centre (Hasan, Robin, Skurkus, Ashmead, Peterson & Shiavi, 1996a). Finally, electromagnetic tracking devices (such as the 3SPACE Tracker (Carrera, Sharpe, Pearcy & Frick, 1996)) have been applied to determine three dimensional postural sway at the level of the pelvis (sacrum). This technique was reported to be a reliable and sensitive method of discriminating between different sensory conditions (Carrera et al., 1996).

Alternative approaches adopting a neurophysiological approach have employed electromyography (EMG) to investigate patterns of muscular contraction exhibited during quiet standing and moreover during dynamic posturography in response to instability and self or externally introduced perturbations. Parameters used in the quantification of sway include the latency, sequencing and amplitude of muscular activity (Prieto, Myklebust & Myklebust, 1993; Winter, 1990; Nashner et al., 1979).

The final method, platform stabilography, involves the use of force platform measures to quantify postural sway. First introduced by Hellebrandt and co-workers (1938),

stabilometry is well accepted within the field of biomechanical research. The three orthogonal components of force have been used in the quantitative evaluation of postural sway (Goldie, Bach & Evans, 1989). However, the centre of pressure (COP), which represents the theoretical point of application of the resultant force vector, has been widely accepted as a measure of postural control. There is a lack of consensus regarding the appropriateness of force versus COP measurements, with the choice influenced by considerations of reliability and sensitivity (Goldie et al., 1989). Information derived from tracking the centre of pressure is different from that obtained from techniques which monitor changes in the position of body and its segments and hence results from the two techniques are not directly comparable (Dean et al., 1986). Platform stabilography is well established and the reliability and sensitivity of such measurements have been consistently demonstrated (Goldie et al., 1989). In addition, platform stabilometry is a readily accessible method, the results of which can be quantified with little difficulty (Hughes, Duncan, & Rose, 1996) and as such is the method of choice in most investigations.

The goal of the postural control system in achieving steadiness or stability is to maintain the position of the mass centre in relation to the base of support (Enoka, 1994; Rothwell, 1994). Since traditionally there have been no direct methods through which the position of the CM can be determined, the COP, obtained from force platform output, has frequently been used in the quantification of postural steadiness. Whilst there are instances in which COP and CM have been mistakenly viewed as synonymous, they are not, and the relationship between the two forms the basis of understanding postural control (Winter, 1990; Ruder, Mackinnon & Winter, 1989). The whole body CM is equal to the weighted average of the CM of individual body segments and is therefore defined by the static position of the body segments (Riley, Mann & Hodge, 1990). In contrast, the centre of pressure, which represents the point of application of the resultant vertical ground reaction force, is a dynamic measure which is sensitive to the accelerations of individual body segments (Winter, 1990). The COP has been described as a neuromuscular control signal (Hasan et al., 1996a; Winter, 1990), the role of which is to regulate the position of the CM ensuring that it remains within the base of support and the body's stability limits (Murray, Seireg & Scholz, 1967). The location of the COP is in theory identical to CM if the subject remains perfectly still and no horizontal accelerations are applied (Lucy & Hayes, 1985; Goldie et al., 1989). Using a combination of force data in synchrony with

an optoelectric imaging system Hasan et al. (1996a, 1996b) examined COP and CM trajectories during quiet stance. While the amplitude and frequency of COP path was greater than that of the CM in both anterior-posterior (AP) and medial-lateral (ML) planes, the two measures were highly correlated (Hasan et al., 1996b). Moreover, the mean position of the COP has been shown to closely approximate the mean position of the vertical location of the CM given an adequate period of sampling (Goldie et al., 1989). A highly consistent ratio was also demonstrated for summary parameters of COP and CM such as the 95% confidence ellipse thus leading Hasan et al. (1996b) to conclude that COP parameters were valid parameters in the quantification of postural steadiness. Hence, it may be concluded that COP is an adequate representation of CM during quiet or quasi-static stance (Hasan et al., 1996a; Riley et al., 1990 op cit. Davis & Grabiner, 1996).

However, the use of the COP to quantify postural steadiness has not been without criticism. Its use is based on the assumption that larger COP excursions are indicative of greater instability (Hasan, 1996a; Slobounov & Newell, 1996). Several authors have been critical of this assumption and have questioned the use of COP parameters to quantify postural steadiness (Panzer et al., 1995; Ruder et al, 1989). Panzer & Hallett (1990) reported the case of an un-medicated patient suffering from Parkinson's disease who demonstrated reduced postural sway despite having what was described as '*severely deficient postural control*' (Panzer & Hallett, 1990 op cit. Panzer et al., 1995). This led Panzer et al. (1995) to suggest that an increased COP movement (sway) may be indicative of either a deficiency in the postural control system or of the adoption of an alternative strategy of postural control. Ruder et al. (1989) was also critical of the use of COP parameters to infer postural steadiness and suggested that both COP and CM should be measured in order to examine mechanisms of balance control.

The inadequacy of indices of steadiness based solely on COP excursions was further questioned during the examination of postural steadiness during transitions between stance conditions. Panzer et al. (1995) cited an example in which the absence of vision resulted in a increase in the excursion of the COP without a concomitant increase in the movement of the CM. This example illustrates that by the use of appropriate joint torques, as evident in the larger COP excursions, the CM may remain relatively still. Given the mechanical definition of steadiness as the maintenance of CM over the base of support, the

quantification of postural steadiness using COP parameters is not without criticism. Despite these valid criticisms COP parameters remain the method of choice in the majority of investigations.

Parameters of postural sway

Time domain

Postural sway can be represented by parameters in both the time and frequency domains. However due to the inherent complexity of the postural control system no single parameter has been devised to adequately reflect postural steadiness or control (Harris, Riedel, Matesi & Smith, 1993; Hageman et al., 1995). Each parameter provides specific information about the postural control system (Le Clair & Riach, 1996). The following parameters have been used to quantify postural sway in the time domain:

i. amplitude
ii. variability
iii. sway path
iv. area

The amplitude of sway has been expressed in terms of the maximum range or peak to peak difference (Geurts, Nienhuis & Mulder, 1993) and the mean amplitude (Hufschmidt, Dichgans, Mauritz & Hufschmidt, 1980; Ekdahl, Jarnlo & Andersson, 1989; Jones, 1991). The mean amplitude has been calculated as the mean distance between the sampling points, the arithmetic mean (Hufschmidt et al., 1980; Jones, 1991) or the geometric mean (Prieto et al., 1993; Goldie et al., 1989; Murray et al., 1975; Thomas & Whitney, 1959). The validity of peak to peak amplitude as an indicator of steadiness has been questioned due to the potential influence of a single large amplitude excursion during an otherwise steady trial (Black et al., 1983; Black et al., 1989). Allum (1990) highlighted the importance of considering directionality in the interpretation of amplitude measures pointing out that given the geometry of the foot a sway backwards is more de-stabilising than one forwards of an equal magnitude.

Measures of variability which have been applied in the quantification of postural sway include the average deviation (Thomas & Whitney, 1959; Murray et al., 1975; Tropp et al., 1984; Soames & Atha, 1980; Hasan et al., 1996b; Hasan et al., 1990) and the standard deviation or root mean squared (RMS) difference (Lucy & Hayes 1985; Harris et al., 1993; Shimba, 1983; Figura, Cama, Capranica, Guidetti & Pulejo, 1991; Zernicke, Gregor, & Cratty, 1982). These measures are useful as they demonstrate an increased resistance to the influence of outlying points. The use of variability measures is based upon the assumption that an increased variability of the COP is associated with instability. However, the global validity of this assumption has been questioned by Newell et al. (1993). The authors cited a study in which the COP profile of developmentally disabled adults (suffering from tardive dyskinesia) exhibited a systematic rhythmical structure which would usually be associated with the successful accomplishment of a postural task. While the mean and standard deviation of the length and area of the COP were generally greater in tardive dyskinesia patients in comparison to control subjects the standard deviation in the anterior-posterior direction was small in relation to control subjects.

Sway path represents the total excursion of the COP (Murray et al., 1975; Jones, 1991) and has frequently been adopted in the quantification of postural sway (Jones, 1991; Hufschmidt et al., 1980; Era & Heikkenen, 1985; Ekdahl et al., 1989; Hughes et al., 1996; Samson & Crowe, 1996; Murray et al., 1975). In order to compare trials of different temporal duration, sway path can be normalised with respect to time. The total excursion of the COP is dependent upon the sampling frequency. The use of a low sampling frequency may lead to aliasing errors and hence reduce the calculated sway path as demonstrated by Murray et al. (1975). The total excursion of the COP best describes the strategies used to maintain balance, however, it provides little information relating to the overall movement of the CM (Hufschmidt et al., 1980).

It is possible that equivalent sway paths may result in a range of sway areas. Given that the goal of the postural control system is to maintain CM within the limits of the base of support, sway area may better reflect the efficiency of the system (Ekhdahl et al., 1989). Area based measures vary according to the criteria of the boundary they include; the area enclosed by the path of sway (Hufschmidt et al., 1980; Ekdahl et al., 1989), average radial area (Hasan et al., 1990) also referred to as circular area (Fitzgerald, Murray, Elliot &

Birchall, 1994), rectangular area (Hasan et al., 1990; Usui, Maekawa & Hirasawa, 1995), elliptical area (Hasan et al., 1990; Tropp et al., 1984; Slobounov & Newell, 1996; Hughes et al., 1996; Fitzgerald et al., 1994; Hasan et al., 1996b; Odendrick & Sandstedt, 1984) and the area of a convex hull (Fitzgerald et al., 1994). Area measurements which include all points may be associated with large standard deviations as a result of outlying points. As a result, sway area is best expressed in terms of standard errors or standard deviations about the mean. The importance of reporting the area measure and moreover the computational algorithm used was highlighted in the discourse between Prieto & Myklebust (1993) and Robin, Hasan, Lichtenstein, Shiavi & Wood, (1993). Robin et al. (1993) used linear regression to determine the elliptical area of sway path while Prieto & Myklebust (1993) defined elliptical area using principal components analysis. Although the correlations between the two methods was high, the algorithm derived using principal components analysis resulted in larger elliptical areas. Therefore, care must be taken when making inter-study comparisons.

Frequency domain

Numerous authors have investigated postural sway using spectral analysis which relies upon the transformation of a signal from the time domain into the frequency domain (Bensel & Dzendolet, 1968; Soames & Atha, 1982; Lui & Dawson, 1995; McClenaghan, Williams, Dickerson & Thombs, 1994; McClenaghan, Williams, Dickerson, Dowda, Thombs & Eleazer, 1996; Harris et al., 1993; Powell & Dzendolet, 1984; Lucy & Hayes, 1985; Watanabe, Yokoyama, Takata & Takeuchi, 1987; Murray et al., 1975). The Fourier transformation, demonstrated by Jean Baptiste Joseph, Baron De Fourier in 1822, permits movement between these two representations (Lynn, 1989). The Fourier series represents the frequencies and amplitudes of a sampled signal as a series of weighted cosine and sine functions. Fourier analysis provides information to complement traditional analyses conducted in the time domain and has the advantage of providing information over the entire test period (Lui & Dawson, 1995). The main disadvantage of Fourier analysis is the inability to locate the point at which unstable episodes occur. This information may be attained using a time-frequency approach as advocated by Schumann, Redfern, Furman, El-Jaroudi & Chaparro (1995) although at present this technique

remains descriptive in nature with quantitative statistical approaches unavailable at the present time (Schumann et al., 1995).

The Fourier transformation and the computationally less complex Fast Fourier Transformation (FFT) algorithm have been applied in the analysis of postural sway to estimate power spectral density, which has been defined as:

> "a technique which yields the distribution of energy at each frequency within a given bandwidth"
>
> Soames & Atha (1982)

The magnitude of energy distributed at each discrete frequency is referred to as the amplitude (mm). However, it is the square of this term, the power (mm^2), which is usually reported. Using power spectral density, postural sway in the frequency domain has been quantified according to the following parameters:

i. variability
ii. mean, median and mode spectral frequencies
iii. spectral area
iv. mean and maximum power frequencies
v. 99% and 99% power bandwidth
vi. slope

Variability of the power spectra has been determined using a measure of frequency dispersion to indicate the distribution of spectral energy (power) about the mean value (Powell & Dzendolet, 1984; McClenaghan et al., 1996). Powell & Dzendolet (1984) reported that the minimum standard deviation occurred at approximately 0.3 Hz with inter-subject variability in power increasing at greater frequencies. Estimates of central tendency including the median and mode spectral frequencies have been used to quantify postural control (McClenaghan et al., 1996). Mean power frequency, which represents the arithmetic mean of the spectrum, is the most frequently cited estimate (Frank, Patla, & Winter, 1989; McClenaghan et al., 1996; Hasan et al., 1996b). Maximum power has also been reported in the measurement of standing balance (Lui & Dawson, 1995; Harris et al.,

1993). Maximum power indicates the magnitude of the strongest perturbation and therefore it shares those limitations associated with peak to peak amplitude measures in the time domain. In particular, maximum power is susceptible to the influence of a single large amplitude excursion during an otherwise steady trial. However, in the evaluation of postural stability maximum power may be a useful parameter to reflect a subject's capacity to respond to an imposed disturbance in their balance. Spectral area is a useful summary parameter which is obtained by calculating the area between the power spectrum curve and the horizontal axis (Lui & Dawson, 1995). There is reported to be an inverse relationship between spectral area and stability, with a large spectral area indicating relative instability (Lui & Dawson, 1995). Alternatively, signal energy may be estimated by summing the power at each discrete frequency up to the Nyquist limit. The 95% and 99% power bandwidths have also been reported, which correspond to those frequencies below which 95% and 99% of the signal power is contained.

In the analysis of postural sway, stationarity is frequently assumed, which implies that statistical parameters (mean and standard deviation) are invariant over the duration of the trial (Carroll & Freedman, 1993; Schumann et al., 1995). There is a lack of agreement in the literature concerning the validity of this assumption. For example, stationarity of the COP signal during double leg stance conditions has been confirmed using a standard run test (Frank et al., 1989). However, several studies have shown this assumption to be incorrect (Carroll & Freedman, 1993; Harris et al., 1993; Newell, Slobounov, Slobounova & Molenaar, 1997; Maki, Holliday & Fernie, 1987; Samson & Crowe, 1996). As a result, the application of those statistics which rely upon a time average may mask important information relating to the temporal control of postural sway (Schumann et al., 1995). The presence of both first order moments (trends) and second order moments has been identified in the postural sway of adults and children (Carroll & Freedman, 1993; Harris et al., 1993). Newell et al. (1997), using a cross-sectional approach, considered changes in the stationarity of the COP across the life-span. While non-stationarity was detected across all trials in the time domain, the frequency domain of the youngest children (3 year olds) demonstrated the greatest degree of stationary. This result was interpreted in accordance with the dynamical systems approach to motor control (Newell et al., 1997) which suggests that the degrees of freedom are heavily constrained in the young child. However, with maturation these constraints are relaxed, and the postural

control system becomes increasingly adaptable to changing environmental demands and hence stationarity may be reduced. Techniques have been presented in the literature to permit the spectral characteristics of non-stationary data to be defined. These include time-frequency and double frequency methods (Harris et al., 1993; Schumann et al., 1995). However, these techniques are at present descriptive in nature (Schumann et al., 1995) and therefore the assumption of signal stationarity remains essential in the quantification of postural steadiness.

Several investigations have attempted to characterise movements or classify groups of individuals according to the profile of their power spectral density (Bensel & Dzendolet, 1968). Powell & Dzendolet (1984) compared the power spectra of athletes with those of sedentary subjects and found clear inter-group differences. At low frequencies (0.02-1.2 Hz) power spectral density values were found to be larger for athletic subjects in comparison to sedentary individuals. However, this trend was reversed at frequencies beyond 1.2 Hz. The authors suggested that by reducing the amount of high frequency sway, athletes may limit the extent of large muscular forces which may be difficult to control and as such may demonstrate greater control and stability. Inter-group differences were also reported in variability across the spectrum. The athletic group demonstrated a relatively consistent standard deviation across all frequencies in contrast to the sedentary group who demonstrated increased variability in frequencies beyond 0.65 Hz.

McClenaghan et al. (1994) also found evidence in support of unique spectral signatures which were suggested to reflect differences in segmental inertia characteristics, sensory function and neuromuscular control. In a subsequent study McClenaghan et al. (1996) used a cross-sectional approach to examine the influence of ageing on the spectral signatures of ground reaction forces. Ageing was found to influence spectral signatures but only in the medial-lateral direction. This highlighted the potential importance of medial-lateral sway parameters and the effect changes in these parameters may have on the decline of postural steadiness of elderly subjects. In a study of young adult subjects Soames & Atha (1982) failed to find support for the existence of spectral signatures concluding that sway patterns were normally and randomly distributed around such events as heartbeat and respiration. However, due to the nature of the subject pool the failure to find support for spectral signatures is not unexpected.

A number of factors have been cited to influence postural sway making cross-study comparisons difficult. Firstly, the duration of the trial has been suggested to be an important factor influencing the outcome and reliability of certain parameters (Le Clair & Riach, 1996). Sway trials have varied from 5 s (Goldie et al., 1994) to 4 mins in duration (Soames & Atha, 1980). The standard deviation of the COP was lowest during intermediate trial durations and was shown to increase as the length of the trial was extended. The optimum reliability was reported to occur at intermediate trial durations (20-30 s) (Le Clair & Riach, 1996). The increase in variability recorded for shorter trials was suggested to be the result of initial instability which decreased as the subject settled on the plate. By contrast, for trials lasting longer than 30 s the increased variability was suggested to reflect periodic changes in the point about which subjects swayed (Le Clair & Riach, 1996).

Stability is also influenced by the size of the base of support (Soames & Atha, 1980; Jones, 1991). A number of authors have suggested that sway parameters may be influenced by foot placement (Kirby, Price & MacLeod, 1987; Samson & Crowe, 1996). Kirby et al. (1987) reported that variations in foot position significantly influenced the total excursion and mean position of the COP. The width of stance was also reported to affect the magnitude of sway parameters, with wider stances associated with reduced postural sway in the medial lateral direction (Rothwell, 1994; Kirby et al., 1987; Samson & Crowe, 1996; Lucy & Hayes, 1985). The reduction in medial-lateral sway was attributed to the increased base of support and the contribution of the hip musculature to stabilise lateral sway. However, large increases in stance width beyond 15cm did not lead to further reductions in medial-lateral sway (Kirby et al., 1987).

The majority of investigations have reported significant but low correlations between height and weight and postural sway (Soames & Atha, 1980; Goldie et al., 1994). Numerous investigations have employed the technique of linear regression analysis to examine the relationship between postural sway and selected anthropometric characteristics. In both adults and children, anthropometric variables resulted in small increases in the amount of explained variance when controlling for the effect of age (Lucy & Hayes, 1985; Hayes, Spencer, Riach, Lucy & Kirshen, 1984; Peeters, Caberg & Mol, 1984; Powell & Dzendolet, 1984; Riach & Hayes, 1987). However, stability is inversely

related to the height of the mass centre above the base of support (Londeree, 1969; Soames & Atha, 1980; Hayes, 1982; Jones, 1991; Enoka, 1994; Hamill & Knutzgen, 1995) and this was shown to be an important factor in postural sway (Powell & Dzendolet, 1984). Stability is greatest in subjects who have a low mass centre, since the mass centre will undergo less displacement for a given angle of sway (Murray et al., 1975; Usui et al., 1995). In adults the mass centre is located in the upper section of the sacrum or more precisely at the level of the 5th sacral process. It is most frequently expressed as a percentage of stature and found to be approximately 55-56% of standing height (Thomas & Whitney, 1959; Hamill & Knutzgen, 1995; Hasan et al., 1996b). The mass centre expressed as a percentage of stature is relatively high in young children in comparison to adult subjects. For example, in female children, the vertical height of the mass centre was estimated to be 59.4% of stature at birth decreasing to approximately 58.0% of stature by 9 years of age (Snyder, Spencer, Owings & Schneider, 1975 op cit. Norris & Wilson, 1995). The relatively high location of the mass centre may in part explain the relative instability observed in young children.

Neurological control of postural sway

Postural control is achieved via a combination of pre-programmed muscle synergies and various sources of afferent information (Nashner & McCollum, 1985). The majority of early research into the control of posture was based upon an inverted pendulum model of the standing human. It was suggested that the mass centre was maintained within the limits of the base of support using an ankle strategy. A distal to proximal sequencing of muscle activation was reported to occur in response to proprioceptive information derived from receptors in the lower legs. However, the extensive research using moving platform posturography has subsequently led to the widespread adoption of a multi-link system (Kuo & Zajac, 1992). Although the ankle strategy may still be valid during quiet stance, in less stable stances a multi-link (ankle-hip) strategy is most appropriate (Nashner & McCollum, 1985; Kuo & Zajac, 1992). Recent research has suggested that afferent information from proprioceptive receptors in the upper body and vestibular input may be in part responsible for generating the muscular actions required to stabilise posture (Keshner & Allum, 1990). In support of this suggestion responses have been detected in trunk and

neck muscles at latencies identical to lower limb proprioceptors (Woollacott & Keshner, 1984).

To maintain upright stability, the central nervous system must rapidly integrate sensory information from vestibular, visual, and somatosensory sources and produce a coordinated response (Dichgans & Diener, 1989; Schumman et al., 1995; Allum, Bloem, Carpenter, Hulliger & Hadders-Algra, 1998). While small disturbances in balance associated with quiet stance may be controlled by the inherent stiffness of the lower limb musculature (Hayes, 1982; Rothwell, 1994), afferent information from the proprioceptive and visual systems is an important component in the maintenance of upright stance (Hayes, 1982; Fitzpatrick & McCloskey, 1994; Rothwell, 1994). The role of the vestibular apparatus is less clearly defined. The vestibular apparatus is made up of the semi-circular canals which are primarily influenced by angular accelerations and the otolith organs which respond to linear accelerations of the head (Maki et al., 1987; Rothwell, 1994). There is reported to be considerable redundancy in the sensory control of postural sway. It has been suggested that the function of this 'redundant' sensory information is to resolve intersensory conflict. In particular, the vestibular system may act as a referent against which afferent information from visual and proprioceptive receptors may be compared. As a result of this comparison, afferent information in conflict with the vestibular referent will be suppressed (Nashner, 1982; Nashner, Black & Wall, 1982).

Postural steadiness has been examined in various stance conditions to determine the influence of vision and the base of support upon various parameters of postural sway. In the literature the Romberg quotient has been defined as the ratio for a given sway parameter between the conditions of eyes closed to eyes open. In adult subjects the extent of sway is greater with the eyes closed when compared with the eyes open (Era & Heikkenen, 1985; Goldie et al., 1994; Frank et al., 1989; Hufschmidt et al., 1980; Lucy & Hayes, 1985; Baloh, Fife, Zwerling, Socotch, Jacobson, Bell & Beykirch, 1994) with the effect of eye closure being most pronounced in the anterior-posterior direction (Hayes et al., 1984; Era & Heikkenen, 1985; Hufschmidt et al., 1980; Lucy & Hayes, 1985). In contrast, in infants and very young children small Romberg quotients have been reported and in some cases the extent of sway was smaller in the eyes closed condition (Hayes et al., 1984; Riach & Hayes, 1987; Odenrick & Sandstead, 1984). The reasons for this

observation have not been conclusively determined but are thought to relate to the way in which children and adults process visual information (Riach & Hayes, 1987). However, children are reported to demonstrate values for the Romberg quotient which are comparable with those of adults by 9-11 years of age (Riach & Hayes, 1987). Studies have also examined the differences in postural steadiness between single and double leg stance conditions (Era & Heikkinen, 1985; Figura et al., 1991; Lui & Dawson, 1995). Although it has been consistently observed that postural sway is greater in single leg stances, the magnitude of the difference between stance conditions varies according to the parameter under investigation.

Development of postural sway within the child

Numerous studies have investigated the development of the postural control system within the growing child, the majority of which have adopted a cross-sectional approach. While cross-sectional studies are helpful in identifying general trends, their utility is limited due to the large degree of inter-individual variability, particularly in very young children (Riach & Hayes, 1987; Figura et al., 1991). This variability may in part be a consequence of the use of chronological age as the index against which the development of postural control is recorded (Riach & Hayes, 1987). Conclusions regarding the development of postural control are further complicated by inter-study differences in the definition of age bands and in the wide variety of parameters used in the quantification of postural sway.

It is accepted that children consistently demonstrate a greater amplitude and rate of sway during quiet stance than adults (Forssberg & Nashner, 1982; Sheldon 1963 op cit. McClenaghan et al., 1994). With increasing age through to adulthood the extent of postural sway decreases and the body becomes progressively more stable (Hayes et al., 1984; Odenrick & Sandstedt, 1984; Riach & Hayes, 1987; Taguchi & Tada, 1988; Foudriat, Di Fabio & Anderaon, 1993; Kowalski & DiFabio, 1995; Hayes et al., 1984). An age-related increase in stability has been reported for most time-based parameters including standard deviation, sway area and sway path (Usui et al., 1995; Zernicke et al., 1982).

Studies investigating frequency content have reported that the increase in postural sway in children is associated with increased energy at the low frequency end of the spectrum (below 2 Hz), with energy at higher frequencies (above 3 Hz) occurring infrequently (Hayes et al., 1984). Riach & Hayes (1987) confirmed that the power spectra of children, 2-14 years of age during 20 s of quiet stance comprised mainly low frequency sway with the principle power in both anterior-posterior and medial-lateral directions being contained within the 0.05-0.70 Hz bandwidth. Sway at higher frequencies, in the 0.8-2.0 Hz bandwidth, was most prevalent in the youngest children (2-5 years) and was found to decrease with age. The presence of higher frequency sway in very young children was purported to be associated with immaturity of the proprioceptive systems and/or the central processing capacity (Riach & Hayes, 1987).

The development of postural control has been investigated by recording muscle activation patterns in response to external perturbations to posture. In a series of studies, the responses of children of various ages to anterior-posterior platform translations were recorded (Shumway-Cook & Woollacott, 1985; Woollacott et al., 1987). Responses to this type of induced disturbance may be indicative of the maturation of the postural control system during quiet stance since all afferent sensory inputs are congruent. In the study by Shumway-Cook & Woollacott (1985) the youngest children (15-31 months) swayed the most even though their postural response patterns were consistent in nature. These young children exhibited the same distal-proximal activation patterns present in adults, however, responses were larger in terms of both amplitude and duration. The amplitude ratios between distal and proximal muscles were consistent, as in adults, inferring close coupling between synergistic groups. These very young children often recruited antagonist muscles, possibly to compensate for the large amplitude agonist responses. However, such co-contraction may be an attempt to increase the stiffness of the musculo-skeletal system as has been reported in elderly subjects (Woollacott, 1993).

Although postural stability increased with age, by 4-6 years children entered into a period of transition in which their responses to postural sway appeared to regress (Shumway-Cook & Woollacott, 1985). In comparison with younger children, older children and adults, the muscle activation patterns of 4-6 year old children were slower and more variable in terms of response latency, amplitude, and amplitude ratios. The period between

4-6 years of age has been described as a period of "substantial variability" (Riach & Hayes, 1990). By 7-10 years of age children demonstrated adult-like responses to postural perturbations. Response latencies of muscles in the lower extremity were shorter and variability was reduced to adult levels. However, the responses of upper body musculature continued to develop into the teenage years and were suggested to mature at around 15 years of age (Woollacott, Debû & Mowatt, 1985; Debu & Woollacott, 1988).

In the very early years postural control develops in a cephalocaudal fashion (Woollacott & Sveistrup, 1992; Woollacott et al., 1987), with responses first appearing in the neck, followed by the trunk and subsequently the legs (Woollacott et al., 1987). The development of postural control is not a linear process (Figura et al., 1991) but rather develops in a stage-like manner (Woollacott & Sveistrup, 1992). Very young children (under 3 years of age) rely primarily upon visual information for the control of quiet stance. Their patterns of muscle activation in response to postural disturbances follow a similar arrangement to adults but are longer and more variable. Young children are unable to suppress extraneous visual information and cannot resolve inter-sensory conflicts. At 4-6 years of age the feedback control of posture appears to regress, the early dominance of the visual system no longer prevails and afferent input from the somatosensory system becomes increasingly important. It has been suggested that the postural strategies that were sufficient to maintain stability in the infant are no longer appropriate given the increasingly complex demands faced by the growing child. Hence, the child enters a period of transition in which they begin to develop alternative adult-like strategies. Using these strategies they become more adept in the integration of sensory information and in the resolution of intersensory conflicts (Shumway-Cook & Woollacott, 1985). By 7-10 years of age, the postural control system is close to maturity and responses in the lower extremity musculature are fully developed in terms of onset latency, variability and temporal coordination (Woollacott et al., 1987).

Influence of training

In addition to changes due to biological maturation, the postural control system is also influenced by previous perceptual-motor experiences. Several studies have investigated the influence of gymnastic training on the development of postural control. Differences in

the postural control system of trained gymnasts and control subjects have been identified in terms of the timing of muscle activation, sensory dominance, adaptation to changing sensory conditions and anticipatory postural control (Debû et al., 1988; Debû & Woollacott, 1988; Pedotti et al., 1989, op cit. Foster et al., 1996).

Debû et al. (1988) investigated the influence of gymnastic training on anterior sway caused by unexpected perturbations of the force platform. While patterns of muscular responses were similar between gymnasts and controls a "significant lengthening of neck muscle latencies" was identified in the most elite gymnasts. This was suggested to be a consequence of the need to control the movement of the head independently, thus permitting visual information to be processed during the performance of complex rotational skills. This hypothesis received only partial support from the study of Debû & Woollacott (1988) which considered the responses to platform translations inducing posterior sway. Once again the general response to sway was similar between gymnasts and controls. However, gymnastic training affected the relative timing of the activation of muscles in the upper body with the direction of the effect being influenced by the length/duration of previous gymnastic training. A limited amount of gymnastic training (2-3 years) appeared to decrease the latencies of muscle activation in response to posterior sway. In contrast, a significant amount of gymnastic training (> 4 years) resulted in the lengthening of the respective latencies. It may be expected that response latencies of muscles in the upper body were more receptive to the influence of training effects than muscles in the lower body. Given the nature of bipedal stance it is likely that daily experience is sufficient to optimise muscle activation within the lower extremities. The unique nature of gymnastic training which involves supporting the body weight using the upper body is likely to induce modifications in the temporal organisation of these responses.

Pedotti et al. (1989) op cit. Foster et al. (1996) reported that skilled gymnasts were able to rapidly modify their patterns of muscle activation in response to alterations in the support surface whereas inexperienced subjects continued to use the same response patterns. Experienced gymnasts were also reported to demonstrate superior anticipatory postural control in relation to control subjects which was suggested to be the result of long-term gymnastic training. However, the studies described above were cross-sectional in nature

and without appropriate longitudinal research it is not possible to conclude conclusively whether the postural control system of gymnasts has been modified by the training process or as a result of self or systematic selection processes.

6.2.2 BALANCE

Balance is considered to be a multidimensional construct comprising both static and dynamic components. In tests of static balance the subject's feet (or hands in an inverted stance) remain fixed in position and performance is usually quantified according to the time a stance can be maintained. Assessments of static balance frequently consist of a series of stance conditions during which the level of difficulty and therefore the challenge to the postural control system is progressively increased (Lees, 1986a). The difficulty of the task may be further manipulated by performing the tasks with the eyes closed (Peltenburg et al., 1982; Clark & Watkins, 1984; Hahn, Foldspand, Vestergaard & Ingemann-Hansen, 1999). Assessments of dynamic balance require the subject to change their spatial location and to assume a specific posture or position (Lees, 1986a). During dynamic balancing activities subjects are required to move their mass centres (CM) outside the base of support (Irrang et al., 1994). Dynamic balance is most frequently assessed using timed functional tests such as beam walking protocols but may include other activities such as landing from jumps (Lees, 1986b; Sol, 1987). Previous research has indicated that the correlation between dynamic and static balance tests is low in adults indicating that they measure different aspects of balance (Peltenburg et al., 1982; Drowatsky & Zuccato, 1967 op cit. Clark & Watkins, 1984).

Balance ability is assumed to be an important component of performance in Women's Artistic Gymnastics (Peltenburg et al., 1982; Irrang et al., 1994) which may be considered particularly important given the demands of the beam apparatus and the requirement to demonstrate stability on landing. However, the intuitive importance of balance ability has not been conclusively supported by experimental research. Sandborn & Wyrick (1969) used multiple regression analyses to examine the relationship between a number of standardised and modified balance tests measured at the commencement of a gymnastic course and a test of balance beam skill conducted 12 weeks later. The majority of tests

were poorly related to balance beam performance. The best predictors of balance beam skill were dynamic in nature and consisted of variants of a side leap test. In a more recent investigation, Hahn et al. (1999) investigated the relationship between unilateral balance and sports participation. Single leg standing balance did not appear to differentiate between athletes competing in eight different sports including artistic gymnastics. This result was unexpected and was suggested to be a possible consequence of the poor response rate and hence small sample of gymnasts involved in the study. Moreover, no relationship was found between standing single leg balance and years of participation in gymnastics.

As outlined in Chapter 2 tests of static and dynamic balance ability have also been included in batteries designed to identify gymnastic talent (Vankov, 1978; Salmela et al., 1979; Peltenburg et al., 1982; Rozin, 1986; Régnier & Salmela, 1987; Sol, 1987; Risack et al., 1988; Poelvoorde & Levarlet-Joye, 1990). Several studies have investigated the relationship between measures of balance ability and performance in various gymnastic disciplines. Sol (1987) included assessments of dynamic and static balance in a battery of physical and perceptual-motor tests designed to identify aptitude in female gymnasts. Dynamic balance was measured according to the stability of landing from jumps from a height of 1.20 m performed with a 180° twist. Static balance was assessed via a single leg balance for 20 s performed with eyes closed on a balance beam. Multiple regression analysis indicated that balance assessments were of low prognostic value in the prediction of future competitive performance. In terms of additional unique variance, static and dynamic balance measurements explained 3% and 0.4% of the variance in the competitive performance achieved 6 months after the initial measurement session.

Peltenburg et al. (1982) measured static and dynamic balance performance in 8-11 year old female gymnasts. Dynamic balance was assessed as the number of steps gymnasts were able to complete on beams of various widths (8, 6, 5, 4, 3, 2 cm) performed initially with eyes open and subsequently with eyes closed. National and club level gymnasts demonstrated superior dynamic balance than control subjects. In the eyes open condition, the greatest differences between groups were observed on the narrow beams, while in the eyes closed condition the largest differences were recorded on the wider beams. Static balance was quantified as the time gymnasts were able to maintain a stork standing

position on an 8 cm beam with the eyes closed. National level gymnasts demonstrated superior static balance in comparison to both club level gymnasts and controls. In the second part of the study Peltenburg et al. (1982) reported that gymnasts who were selected as talented demonstrated better static and dynamic balance than gymnasts who were initially selected as talented and subsequently discharged and those who were not selected. However, in the dynamic balance condition, the difference between groups was only significant in the eyes closed condition.

Kioumourtzglou et al. (1998) used a stabilometer platform to measure dynamic balance in members of Greek National Rhythmic Gymnastics Squad. Dynamic balance was defined as the time (s) that gymnasts were able to maintain the platform within 10° of the neutral (0°) position during a 90 s measurement period. Dynamic balance was not related to overall competitive performance in 11-12 year old gymnasts but was significantly but negatively correlated with performance in the older group of 13-15 year old gymnasts ($r=-0.38$, $p<0.05$). This result was interpreted to be the possible consequence of either the greater height of the older gymnasts or their attempts to adopt a more 'mature' pattern of balance control, which caused their balance performance to regress. However, the validity of the latter suggestion may be questioned since developmental research has indicated that the postural system is close to maturity by 10 years of age (Shumway-Cook & Woollacott, 1985).

An apparent regression of balance performance was also observed in Canadian male artistic gymnasts. In a longitudinal study Jancarick & Salmela (1987) investigated balance in inverted and upright stances in nine male gymnasts at two points in time separated by a measurement interval of six years. The mean age of gymnasts at the initial measurement session was 17.8 years. Balance performance decreased between the two measurements however, due to the large standard deviations the decrease was not statistically significant. The decrement in performance was suggested to be the result of changes in the motivation of the gymnasts. Jancarick & Salmela (1987) also conducted a cross-sectional comparison between the nine elite national squad members measured in 1983 and the initial measurements from gymnasts of various age groups tested in 1977. In contrast to the results of the longitudinal investigation, this comparison indicated that balance improved with age and experience. Balance in an upright stance was reported to be a prognostic

indicator of current performance in Men's Artistic Gymnastics (Régnier & Salmela, 1987). In a multiple regression analysis, which included 20 variables which were positively correlated with competitive performance, balance in an upright stance was among the five variables which explained the greatest percentage of variance in 50% of the age groups studied. Balance in the handstand position was also an important predictor of performance in gymnasts in the youngest and next to oldest age groups (10-11years and 17-19 years).

There has been little research concerning the role of genetic factors in determining balance ability, with large variability observed in the heritability estimates reported across studies (Malina, 1986; Bouchard et al., 1997). As part of a broader investigation Maes et al. (1996) examined the influence of genetic factors upon flamingo balance in 10 year old twins and their parents. Initial correlations between MZ and DZ twin pairs indicated that genetic factors accounted for little of the phenotypic variance in the single leg balance test. However, results of the path analysis indicated that genetic factors accounted for over 40% of the variance in both the twin only and the combined twin and parental data sets (Maes et al., 1996). In summary, as a result of the inconsistent findings reported in the literature, it is not possible to quantify the extent to which balance ability may be a stable characteristic suitable for inclusion in an initial identification battery.

6.2.3 KINAESTHESIS

Kinaesthesis has been referred to as the sense of position and movement (Laszlo & Bairstow, 1985a; Hoare & Larkin, 1991). However, in a more detailed definition Rodier, Euzet, Gahery & Paillard (1991) described kinaesthesia as;

> "the ability we have, when our eyes are closed to perceive and evaluate the relative positions of our skeletal body parts as determined by the joint angles to detect the direction and speed of change in those positions during ongoing movements"
>
> (Rodier et al., 1991)

Kinaesthesis is a compound sense which includes three main sensations; the sensation of joint position and movement, the perception of force or effort associated with muscular

contractions and the perceived timing of muscular actions (McCloskey, 1987; Gandevia, McCloskey & Burke, 1992; Enoka, 1994). The majority of research has investigated the sense of joint position and movement with little research interest devoted to the other kinaesthesic sensations.

Joint position sense

Afferent information from various sources including skin (cutaneous), muscles and tendons, joint capsule and ligaments is combined to signal joint position and movement (McCloskey, 1978; Grigg, 1994). However, information derived from intra-muscular receptors is acknowledged to be the most important source in determining the position and movement of a joint (Gandevia et al., 1992; McCloskey, 1987; Grigg, 1994). Joint receptors play a limited role in signalling joint position and movement in the mid-range of joint excursion (McCloskey, 1978; Gandevia, 1987) with their contribution becoming increasingly significant at extreme joint angles (McCloskey, 1978). The enhanced sensitivity of certain articular receptors at the extremes of joint motion may be considered particularly significant given that the ability of intra-muscular receptors to signal joint position is reduced at these angles (McCloskey, 1978). Finally, cutaneous receptors are reported to contribute little to static position sense but are thought to play a more significant role in the detection of joint movement (Grigg, 1994). It has been suggested that the main role of cutaneous receptors may be to facilitate afferent information derived from sensory receptors in the muscles and joints (McCloskey, 1978).

A number of procedures have been devised to quantify the sense of limb position or movement. The most widely used assessment has been the kinaesthetic sensitivity test (KST) which was originally developed and subsequently modified by Laszlo & Bairstow (Laszlo & Baristow, 1980; Bairstow & Laszlo, 1981; Laszlo & Bairsto, 1983; Laszlo & Bairstow, 1985a,b). The KST measured two aspects of kinaesthesia. Firstly, kinaesthetic acuity was assessed as the ability of subjects to discriminate between the height of two inclined runways in the absence of vision. Kinaesthetic acuity was determined for passive limb movement using the method of constant stimuli and initially defined as the minimum difference in runway height that subjects were able to detect (Laszlo & Bairstow, 1980). However, in subsequent publications acuity was redefined according to the total number of

correct responses (Laszlo & Bairstow, 1980; Laszlo & Bairstow, 1985a). The second component of the KST determined the extent to which subjects were able to perceive and memorise kinaesthetic information. In this cross-modal test, vision was excluded while the subject's hand was passively traced around a shaped perspex stencil. The stencil was rotated out of view of the subjects who were then required to reorientate the stencil to its original position. Vision was permitted during the reorientation phase.

The KST was used to generate normative data for children and adults and to examine the relationship between kinaesthetic ability and motor performance. A positive relationship was reported between kinaesthetic sensitivity and drawing performance (Bairstow & Laszlo, 1981). However, the KST and in particular the author's use of the method of constant stimuli to determine the difference threshold has received criticism (Doyle, Elliot & Connolly, 1986; Elliot, Connolly, & Doyle, 1988). According to Doyle et al. (1986) the range of stimuli and number of trials used to determine the difference threshold were inappropriate for the youngest children. As a result the difference threshold was derived using extrapolation which resulted in an inaccurate threshold. This limitation may in part explain the poor reliability of the kinaesthetic acuity test in children reported by & Bairstow (1985a). Elliot et al. (1988) applied a staircase elimination method to the active test of kinaesthetic acuity designed by Laszlo & Bairstow (1980) and reported moderate correlations between kinaesthetic acuity and performance in eight motor tasks. However, regression analyses highlighted the common effect of age with the unique contribution of kinaesthetic acuity to variance in motor performance reported to be negligible.

In addition to the KST, a number of methodological approaches including matching and linear positioning tasks have been employed to evaluate kinaesthesia. Matching tasks require the subject to 'match' or replicate a specified target angle/position with results expressed in terms of the deviation in degrees between the subject's estimate and the target angle/position (Scott & French, 1959; Régnier & Salmela, 1987; Euzet & Gahery 1995; Kioumourtzoglou et al. 1998). Linear positioning tasks have also been applied which require the subject to indicate the length of a previously defined linear measurement (Carlton & Newell, 1985; Cox & Walkuski, 1988; Hoare & Larkin, 1991). Previous investigations have consistently reported low correlations between the results of tests used to measure kinaesthesia which suggests they may be measuring different aspects of

kinaesthetic sense (Laszlo & Bairstow, 1985a). This independence may be explained in terms of the extent to which each source of afferent information contributes to signal joint position and movement which is dependent upon the conditions of the task and solution adopted by the subject (Burgess et al., 1982; Elliot et al., 1988; Hoare & Larkin, 1991).

Irrespective of the particular methodological approach adopted, the choice of task mode, frame of reference and the nature of limb positioning may influence the estimation of kinaesthetic sense. Task mode is an important consideration in the assessment of kinaesthetic sensitivity, with tasks classified as intra or cross-modal. A matching task may be described as intra-modal when the criterion and result of the matching process are defined in the same mode. For example, a kinaesthestic-kinaesthetic task (K-K) may require the subject to replicate an angle assumed by one limb using the collateral limb. Conversely, in cross-modal tasks, the criterion and result of matching are defined in different modes. For example, a visual-kinaesthetic task (V-K) may require the subject to view a visual image of a joint angle and match the angle using their own limb. Studies of athletes and control subjects have demonstrated the lack of any significant relationship between the results of intra and cross-modal tasks (Rodier et al., 1991; Euzet & Gahery, 1995) which suggests they may be measuring separate aspects of position sense. In addition, the prevalence of errors was reported to vary in relation to mode, with a greater number of errors being reported in cross-modal tasks compared with intra modal tasks (Rodier et al., 1991; Euzet & Gahery, 1995). The increased incidence of errors was hypothesised to be the result of the greater cognitive demands associated with cross-modal transfers (Rodier et al., 1991). Finally, within a cross-modal matching task, the V-K condition resulted in the consistent overestimation of the criterion angle while a K-V condition resulted in the systematic underestimation of the criterion angle (Rodier et al., 1991). This was suggested to indicate a systematic difference in the way joint angle information is represented by the visual and kinaesthetic systems.

It may be hypothesised that the development of skill in gymnastics requires proficiency in both intra-modal and cross-modal matching tasks. Intra-modal matching ability may be particularly important in very young gymnasts where considerable emphasis is placed upon the 'shaping' of skills. During the initial stages of gymnastic preparation the coach may 'carry' gymnasts through progressions stressing the importance of attaining the correct

shape within each phase of the skill. In contrast, during the later stages of development the gymnast may incorporate cross-modal matching to a greater extent and in particular may become proficient at creating an image of the skill based upon the performances of peers and/or instructions of the coach.

A second important consideration concerns the frame of reference used to code limb position or movement. Velay, Roll & Paillard (1989) used prismatic exposure to investigate the spatial reference frames adopted in pointing and matching tasks. Exposure to a prism affected performances in the pointing task but not in the matching condition. Since both tasks relied upon similar afferent information, the central representation of joint configuration was considered to be responsible for the differences observed in response to prismatic exposure. Specifically, limb configuration was assumed to be coded with respect to the postural coordinate system in the matching task and relative to an extrapersonal frame of reference in the pointing task. It may be hypothesised that given the range of skills performed by the elite female gymnast the adoption of both postural and extrapersonal frames of reference are required. The adoption of extra-personal frames of reference may be clearly illustrated by considering contemporary asymmetric bar routines in which gymnasts frequently perform complex release and re-catch skills.

The final consideration relates to the manner in which the target limb is positioned. It has been well established that the accuracy with which limb position may be detected is dependent upon whether the criterion position of the target limb is attained actively or passively (Jeannerod, 1989; Velay et al., 1989). Velay et al. (1989) highlighted that active positioning of the target limb enhanced accuracy in both pointing and matching tasks (Velay et al., 1989). Moreover, kinaesthetic acuity is also enhanced when the limb is moved actively, with lower detection thresholds reported during active movement conditions (Gandevia et al., 1992; Grigg, 1994). The increase in kinaesthestic sensitivity and acuity associated with active muscular contraction has been attributed to the augmentation of afferent information from peripheral sensory receptors and a possible contribution of central efferent information (Velay et al., 1989). It is well established that the sensitivity of sensory receptors is increased during active muscular contraction with the greatest augmentation occurring in intra-muscular receptors (McCloskey, 1978; Gandevia et al., 1992). In contrast, the role of efferent mechanisms in the determination of joint

position has not been clearly determined (Jeannerod, 1989). Bairstow & Laszlo (1981) measured passive kinaesthetic sensitivity in an attempt to ensure that the measurement of kinaesthesia would not be confounded by poor motor control (Laszlo & Bairstow, 1983). The choice of passive assessment may be considered appropriate when working with very young children or with subjects demonstrating impaired performances in perceptual-motor tasks. By assessing kinaesthetic ability in isolation the precise nature of the impairment may be identified and an appropriate action plan formulated to address the deficit. However, in subjects with adequate or high levels of motor control the use of passive assessments may be associated with low external validity. Therefore, the use of active positioning is considered a more sensitive and generally more appropriate approach (Elliot et al., 1988; Gandevia et al., 1992; Freeman & Broderick, 1996).

The importance of kinaesthesis in technical sports such as gymnastics is self-evident given the nature of elite performances and the progressive development of skills associated with the acquisition of expert status. However, there is little consensus in the literature concerning the relationship between kinaesthesis and athletic proficiency. Euzet & Gahery (1995) compared lower limb kinaesthetic sensitivity in mixed sex groups of athletes from a range of eight sports, including gymnastics, and non-athletic controls. The athletes demonstrated smaller errors than control subjects in both intra and cross-modal matching tasks. Several hypotheses were suggested to explain the superior performances of athletes which included genetically determined differences between athletes and controls and the possible influence of training upon the development and/or sensitivity of sensory receptors (Euzet & Gahery, 1995). Moreover, the proficiency of athletes in the cross-modal tests may be the result of their enhanced ability to transfer conceptions of position sense between sensory modalities.

Bairstow & Laszlo (1981) reported no differences between gymnasts/ballet dancers and controls in terms of kinaesthetic acuity but showed that the gymnasts were able to process and memorise kinaestheic information more efficiently than controls subjects and athletes from other sports (Bairstow & Laszlo, 1981; Laszlo & Bairsto, 1983; Laszlo & Bairstow, 1985a). However, in a subsequent investigation Freeman & Broderick (1996) found no differences in either component of the kinaesthetic sensitivity test (Laszlo & Bairstow, 1985a) between mixed-sex groups of elite adolescent athletes participating in

ballet/gymnastics, basketball and age matched controls. The absence of group differences for the kinaesthetic perception and memory test was in contrast to the findings of Bairstow & Laszlo (1981) but may be attributed to the pooling of male and female subjects into a single group. Although a non significant main effect was reported for sex, a significant interaction effect was observed for sex and group. Specifically, female dancers/gymnasts demonstrated more accurate kinaesthetic perception and memory than males, with the opposite result being observed for the control group. Although the differences in kinaesthetic perception and memory between single sex groups of athletes and controls were not investigated, Freeman & Broderick (1996) suggested that given the nature of the sport, kinaesthetic ability may not be a particularly important attribute within elite male gymnasts. Further support for this suggestion may be derived from the study by Régnier & Salmela (1987) which examined the relationship between joint position sense as assessed through cross-modal matching and competitive performance in elite male gymnasts. Multiple linear regression revealed that joint position sense was among the five best predictors of competitive performance in only one age group (12-13 year old male gymnasts). However, the apparently poor predictive validity of joint position sense must be interpreted in the light of the poor reliability which appears to plague such field based assessments of perceptual-motor abilities.

In summary, although the widespread use of mixed sex samples has limited our understanding of the relationship between kinaesthetic sensitivity and athletic proficiency, the majority of studies have indicated that athletes demonstrate superior position sense in comparison to control subjects. Female gymnasts do not appear to have superior kinaesthetic acuity in relation to untrained control subjects (Freeman & Broderick, 1996; Bairstow & Laszlo, 1981; Laszlo & Bairstow, 1985a) but may be better able to process and memorise kinaesthetic information. The superior kinaesthetic sensitivity demonstrated by gymnasts and other athletes was suggested to be the result of sports specific training (Euzet & Gahery, 1995). However, the causality of the relationship and therefore the role of innate ability remains to be determined.

The development of kinaesthetic sensitivity within the growing child appears to be task specific (Hoare & Larkin, 1991). In a cross-sectional investigation, Laszlo & Bairstow (1980) reported that active kinaesthetic acuity improved with age with the majority of

improvement occurring between 5-7 years of age. Moreover, most children demonstrated adult levels of acuity by 7-8 years of age. In contrast, the results of cross-sectional investigations employing the kinaesthetic perception and memory test revealed that children are not fully able to utilise kinaesthetic information until considerably later (Laszlo & Bairstow, 1980). A similar pattern was observed when kinaesthesis was measured passively although the rate of improvement was more gradual (Bairstow & Laszlo, 1981). However, studies using the KST have consistently revealed a wide range of individual differences with some children as young as 5 years of age demonstrating adult levels of kinaesthetic senitivity (Laszlo & Bairstow, 1985a). There have been no attempts to investigate the longitudinal development of kinaesthetic sensitivity in an athletic population.

Perception of force

The ability to perceive and subsequently generate the amount of muscular force or effort required to complete a particular element may be considered an important attribute of the elite gymnast. A combination of afferent and efferent information are integrated to enable subjects to perceive the muscular force or effort associated with a given muscle action. Afferent information is provided by the golgi tendon organs which are sensitive to changes in muscular tension (Enoka, 1994). However, the perception of force is based primarily upon efferent information which indicates the magnitude of the motor command generated within the central nervous system (McCloskey, 1978; Enoka, 1994).

The ability of subjects to perceive and subsequently reproduce muscular force has been quantified in both the upper and lower extremities using a variety of protocols. Régnier & Salmela (1987) examined the ability of male gymnasts to reproduce muscular force using a grip dynamometer. Gymnasts were required to produce maximal force and given two attempts to reproduce 50% of their measured maximal force. The distance perception jump test has also been used to measure the ability of children to perceive and reproduce muscular force (Johnson & Nelson, 1986 op cit. Kirby, 1991). Subjects were required to stand behind a start line and judge the distance to a target line placed 24 inches in front of the start line. Subjects were instructed to close the eyes and jump to land on the target line with the error recorded in terms of the distance from the target line. In a critical review,

Goldman (1991) suggested that subjects were likely to experience difficulty in maintaining voluntary eye closure during the jump (Goldman, 1991). However, more significantly, jumping with the eyes closed may be considered a dangerous and threatening situation particularly for young children. Moreover, the use of a standard distance may potentially limit the validity of the task providing a different challenge across individuals of various jumping ability.

Perception of timing

There is very little information available concerning how the timing of movements are perceived, however, perception is reported to be based upon the integration of afferent and efferent information (McCloskey, 1978). This contention is based upon the observation that subjects are able to differentiate between the centrally generated command to initiate movement and the afferent information derived from the sensory receptors to indicate that movement has commenced (Enoka, 1994). In one of the few studies to examine time estimation in athletes Régnier & Salmela (1987) recorded the accuracy with which male gymnasts were able to reproduce time delays of 20 s, 10 s and 5 s using a hand held stopwatch.

Perception of rotation

Rotation is perceived using proprioceptive information derived from the semi-circular canals which are sensitive to accelerations. In contrast to kinaesthetic information, proprioceptive input need not necessarily be perceived and may include information derived from the sensory receptors within the vestibular apparatus (McCloskey, 1978; Enoka, 1994). Régnier & Salmela (1987) estimated gymnasts' ability to perceive rotation using a turntable. After a period of familiarisation, subjects closed the eyes and initiated sufficient rotation of the turntable to complete 1080° (three complete revolutions). The gymnast was required to signal the instant they perceived 720° (two complete rotations) had been completed. The error in degrees was noted with over and under-estimations recorded. Although moderate to high correlations were observed between the perception of rotation and performance in the majority of age groups it was not among the first five predictors of performance in any age group. In a follow up investigation Jancarik &

Salmela (1987) reported that the ability of elite male gymnasts to perceive rotation decreased over a six year measurement interval. However, as a result of the large variability in performances, this decrement did not reach statistical significance. Age-related changes in the perception of rotation were also investigated by comparing performances in this elite group with groups of gymnasts involved in the previous study (Régnier & Salmela, 1987). The cross-sectional data revealed that the ability to perceive rotation increased progressively with age, with absolute errors decreasing from 44° in the youngest age group (under 12 years of age) to 4.4° in the elite group (23.9 years).

6.2.4 ELECTROMECHANICAL RESPONSE TIMES

Reaction time has been defined as;

> "a measure of the time delay from the arrival of a suddenly presented and unanticipated stimulus to the beginning of some pre-determined motor response to it."
>
> (Grouios, 1991)

Some studies define the end point in terms of limb movement (Winter & Brookes, 1991) while other studies deem the end of reaction time to occur when a specified level of force has been produced (Bell & Jacobs, 1986). However, the time to reach a relative force threshold, for example a certain percentage of maximum force, may be a more appropriate parameter in the assessment of reaction time in children who are not expected to elicit large output forces.

The reaction time of adults subjects in response to an auditory stimulus has been reported to be in the region of 170-180 ms (Hascelik, Basgöze, Türker, Narman & Özker 1989, Andersen, Starck, Rosén & Svensson, 1984). Total reaction time has been fractionated into pre-motor (PRT) and electro-mechanical delay times (EMD) as shown in Figure 6.1. Pre-motor time refers to the time from the presentation of a stimulus to the change in EMG activity and relates to events prior to the afferent signal reaching the muscle. It is largely associated with the time required to process information (Magill, 1989) and more specifically, the selection and programming of an appropriate response (Clark, 1982).

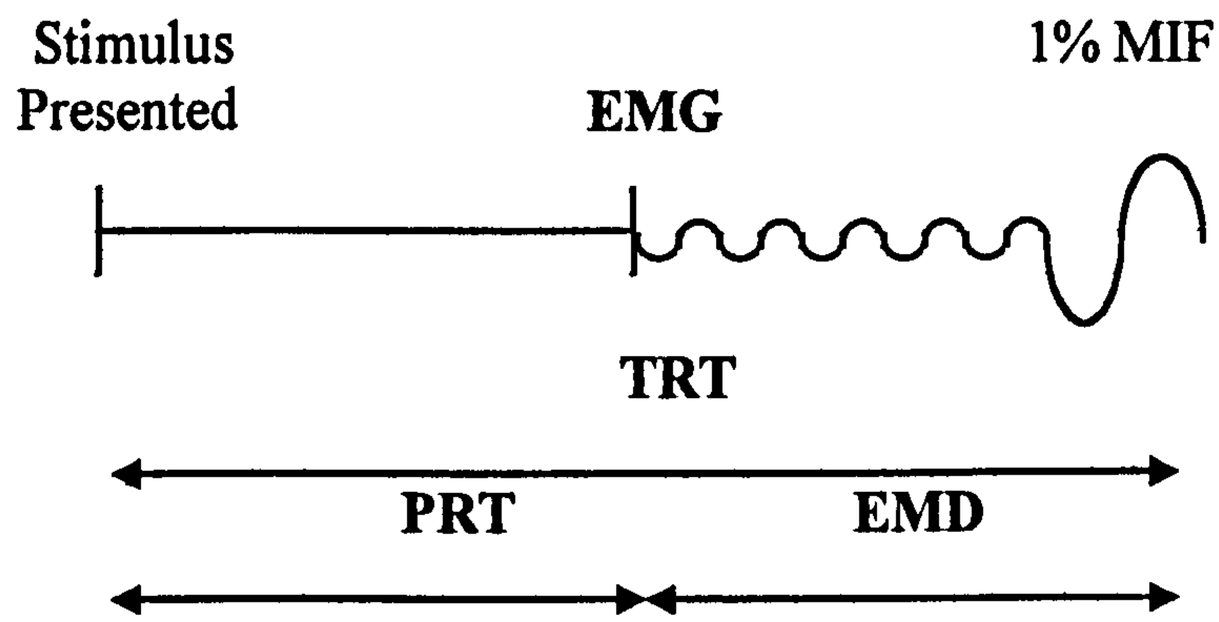


Figure 6.1. "Events in the reaction time paradigm" Adapted from Schmidt & Lee (1999).

where:

TRT	Total Reaction time	Time from the presentation of the stimulus to the development of tension in the muscle
PRT	Pre-motor time	Time from the presentation of the stimulus to the activation of EMG
EMD	Electromechanical Delay Time	Time from onset of EMG to the development of tension in the muscle

The EMD represents the time interval between the change in EMG activity and the subsequent onset of force generation (Komi, 1979). EMD was previously estimated to last between 20-100 ms (Komi, 1979, 1984). The width of this range has been attributed to the application of various thresholds to determine the development of muscular tension (Komi, 1979). However, a narrower time epoch has recently been proposed of 40-80 ms (Schmidt, 1988). The EMD comprises events associated with excitation and contraction coupling and the lengthening/stretching of the Series Elastic Components (Komi, 1984; Asai & Akoi, 1996).

The contribution of the latter was suggested to be of primary importance (Komi, 1984) and as such the magnitude of the EMD was suggested to vary according to the mode of testing, with the shortest EMD's expected in eccentric muscle actions (Komi, 1979). However, Jöllenbeck (1998) estimated the EMD in explosive maximal isometric voluntary

contractions with the hamstrings in six different length positions. The results indicated that the shortest EMD occurred in an optimal rather than stretched muscle length, thus questioning the influence of the SEC. It has also been suggested that there is a relationship between EMD and muscle fibre type, with those muscles composed of mainly fast twitch fibres having a shorter EMD (Komi, 1979, 1984).

Estimated reaction times vary between studies due to the nature of the stimulus with shorter reaction times for audio in comparison with visual stimuli (Hascelik et al., 1989). A direct comparison of estimates of reaction time between studies is further hindered by inter-study differences in the age and sex of subjects (Grouios, 1989). Gender differences in reaction times are well established. Female subjects have been shown to have longer electromechanical response times, attributed to the increased elasticity of musculo-tendinous units and in particular the greater responsiveness of the SEC to stretch (Komi, 1984; Bell & Jacobs, 1986). Inter-individual differences have also been linked to variations in muscle fibre types (Komi, 1984; Bell & Jacobs, 1986).

Generally athletes have demonstrated faster reaction times than non-athletes (Taimela, 1992 op cit. Thomas & Mitchell, 1996), but this has not proved universally true for all athletic pursuits. Haubenstricker et al. (1986) confirmed that there were no significant differences in fractionated reaction times between distance runners and control subjects. Similiarly, Mero et al. (1990) found no significant differences in simple reaction time between control subjects and promising male pre-pubescent athletes involved in weight lifting, endurance running and sprint running. However, differences were found between the athletic and control groups for choice reaction time, with the athletic group demonstrating a significantly shorter reaction time to light stimulus. Similarly, Thomas & Mitchell (1996) failed to find a significant difference in visual reaction time between elite gymnasts, endurance runners and sedentary subjects which led them to suggest that simple visual reaction time may not be sufficient to reflect the demands of the sport. These results indicated that differences in the neural pathways associated with simple reaction times are unlikely to contribute to self-selection of gymnasts.

Reaction time has consistently been demonstrated to be influenced by age. Table 6.1 highlights the mean values for reaction time reported across a number of studies.

Table 6.1. Reported reaction times for children and adolescents

Study	Age(years)	Gender	Signal	RT(ms)
Grouios (1991)	6 – 10	male	audio	290
	11 – 15	male	audio	259
Thomas et al. (1981)	7	female	visual	438 ± 98
	9	female	visual	363 ± 78
	11	female	visual	324 ± 62
Andersen et al. (1984)	7		audio	353
	9		audio	287
	11		audio	244
Mero et al. (1990)				
Weight lifters		male	audio	179 ± 23
Endurance runners		male	audio	168 ± 19
Sprint runners		male	audio	179 ± 25
Controls		male	audio	179 ± 25

The developmental progression of reaction time has been well documented (Andersen et al., 1984; Fuchigiani, Okubo, Fujita, Okuni, Noguchi & Yamada, 1993; Grouios, 1991; Thomas, Gallagher & Purvis, 1981; Nicholson, 1982) however, the majority of studies are limited by their use of a cross-sectional design. In such investigations, the analysis of mean results frequently masks the individual variation that occurs at each age level (Fuchigami et al., 1993). Reaction times have been consistently reported to decrease as a function of age (Thomas et al., 1981; Eckert & Eichorn, 1977; Hascelik et al., 1989).

The age at which this decrease begins to plateau and reaction time stabilises was reported to be around 15-16 years of age (Andersen et al., 1984). In contrast, some studies have indicated that reaction times continue to decrease through childhood and adolescence into the early twenties (Grouios, 1991). The relationship between age and reaction time has been reported to be curvilinear (Fuchigani et al., 1993). Unlike the Gaussian or normal distribution of reaction times in adult subjects, the reaction times of children were reported to be a skewed distribution which required normalisation via the application of a

logarithmic transformation (Andersen et al., 1984). In addition to the increased duration, reaction times were reported to be more variable in younger children, for both choice reaction time tests (Fuchigani et al., 1993) and simple visual reaction time tests (Thomas et al., 1981), indicating the variability associated with the immature cognitive system.

Reasons for the decreases in reaction time with increasing chronological age are not fully understood. They are not thought to be associated with reductions in peripheral transmission time, as adult levels are attained relatively early in development (Andersen et al., 1984). There is a general consensus that the decrease in reaction time is associated with an increase in central processing capacity (Grouios, 1991; Schmidt, 1988). The magnitude of the increase in processing capacity must be considerable given that the height of children and hence the distance of the efferent neural pathways increase during childhood and adolescence. With respect to fractionated reaction time, Asai & Akoi (1996) demonstrated that the EMD was significantly longer in children (77 ± 12.4 ms) than adults (42 ± 7.7 ms) during isometric elbow flexion ($p<0.001$). Children's EMD was estimated to be 1.8 times that of adult subjects which was attributed to age associated differences in contraction speed and the extension of the SEC (Asai & Akoi, 1996).

The extent to which reaction time is a heritable characteristic has not been fully determined. Studies have reported that reaction times are influenced by environmental factors with decreases in reaction time associated with prolonged training. For example, the auditory reaction time of volley ball players was reported to decrease in response to an 8 week training from 191.3 ms pre-training to 175.1 ms post training (Hascelik et al., 1989). While the precise mechanisms responsible for such a decrease remains to be quantified, the type and amount of training does not appear to be associated with the function of the somatosensory nerves. For example, the conduction speeds of the afferent pathways were reported to be similar in elite gymnasts and untrained/sedentary subjects (Thomas & Mitchell, 1996). Further support for the contribution of the genotype to peripheral nerve conduction velocity can be gained from the study by Rijsdijk, Boomsma & Vernon (1995) which reported heritability estimates of 0.77. Several studies of children and adolescents twin pairs have indicated that although the patterns of intra and inter-pair variances indicate a genetic component to reaction time, the influence of the genotype is low to moderate. For example, in a recent review of research Bouchard et al. (1997)

reported a range of heritability estimates between 0.22 (Vandenberg, 1962) and 0.55 (Sklad, 1973) for reaction time to a light stimulus. Path analysis of family data confirmed that the transmissibility of reaction time in response to a light stimulus was low (0.27) but indicated that the majority of this transmissibility was associated with a genetic effect (0.20).

6.3 METHODS

Postural sway

Collection of force and video data

Force and video data were collected as detailed in Section 5.3 (Figures 5.11 and 5.17). Force ranges were set to 1 kN full scale deflection (FSD) vertical and 1 kN FSD horizontal. The analogue force signal was amplified and passed through an anti-aliasing filter with a cut-off frequency of 256 Hz. The point of force application in the medial-lateral (a_x) and anterior-posterior (a_y) directions were produced from the analogue data according to the following equations:

$$a_x = \frac{F_x * a_z - M_y}{F_z} \qquad a_y = \frac{F_y * a_z - M_x}{F_z} \qquad (6.1)$$

where:

a_z = vertical offset of Kistler load cells

F_x = medial-lateral reaction force

F_y = anterior-posterior reaction force

F_z = vertical reaction force

M_x = moment about the medial-lateral axis

M_y = moment about the anterior-posterior axis

The centre of pressure data were converted into a binary signal via a 12 bit Laboratory interface analogue to digital converter (CED 1401 ADC) at a sampling rate of 50 Hz. The data were recorded on floppy disc and stored as binary files using an Acorn A5000 RISC personal computer.

Procedure

Gymnasts were required to adopt three stance conditions on the force platform; double leg stance eyes open (DO), double leg stance eyes closed (DC) and single leg stance eyes open (SO). Prior to data collection, each stance condition was demonstrated by the recorder and subjects were permitted a period of familiarisation. To control for any order effects the stance conditions were presented as one of two sequences (DO, SO, DC and DO, DC, SO). Approximately 50% of the sample completed each sequence with selection based on club membership. One acceptable trial was collected in each stance condition, with a maximum of three attempts. The duration of each trial was 20 s and a rest period of approximately 60 s was provided between trials to reduce fatigue. Gymnasts were allowed to use their preferred leg for the SO condition as it has been previously reported that leg dominance did not significantly influence the parameters of postural sway (Jones, 1991; Goldie et al., 1989; Goldie, Evans & Bach, 1992).

Subjects were informed that the goal of the assessment was to stand as still as possible with the arms held in a relaxed position by the sides. In the visual stance conditions subjects were asked to focus upon a target 1.30 m high and a distance of 6 m from the centre of the force platform. In the single leg stance, subjects were instructed to place the standing foot in the centre of the force platform, for the double leg stance conditions subjects were required to stand in the centre of the force platform placing the medial arches of the feet 0.05 m apart. Once the subject indicated readiness, the data capture system was initiated by a manual trigger which also triggered an array of light emitting diodes (LEDs) and provided an audio signal to the gymnast. A second audio signal indicated the termination of data collection. Any fall, touchdown or opening of the eyes was manually recorded by the operator and the trial was repeated.

In an attempt to limit non-stationarity subjects were provided with a period of time to assume the required stance prior to data capture to reduce the influence of initial transients shown to be most prevalent in the first 20 s of quiet stance (Carroll & Freedman, 1993). In addition, the data capture period was selected in accordance with the literature which has reported 20 s to be the optimum duration to maximise stationarity (Carroll & Freedman, 1993; Harris et al., 1993).

Analysis

Time domain parameters

The standard deviation of the COP was determined in the medial-lateral (a_x) and anterior-posterior (a_y) directions. Sway path, defined as the sum of the distances between sequential COP positions, was estimated using trigonometry (Figure 6.2) according to the following formula:

$$\text{Sway Path (s)} = \sqrt{\sum_{i=1}^{1024}(x_i - x_{i+1})^2 + (y_i - y_{i+1})^2} \qquad (6.2)$$

The sway area was described as the area of an ellipse whose vertices were defined by 1.96 standard deviations of the COP in the anterior-posterior and the medial-lateral directions. Postural sway in each stance condition was represented visually using a time-series plot of the COP position (stabilogram) using the SwayDraw program (Kerwin, 1997, unpublished). For all the stabilograms presented in this chapter the dimensions of the force platform have been reduced by a factor of ten in relation to the magnitude of the sway path. To standardise the stabilograms the mean medial-lateral and anterior-posterior location of the COP has been subtracted from each data point so that the sway path appears in the centre of the force platform. Figure 6.3 shows an example stabilogram for each stance condition indicating the elliptical area enclosing 95% of the points. In addition, a linear regression line derived using a least squares fit was marked and the ellipse rotated so that the axis corresponding to the major vertex lay along this line. This provided an indication of the prevalent direction of sway.

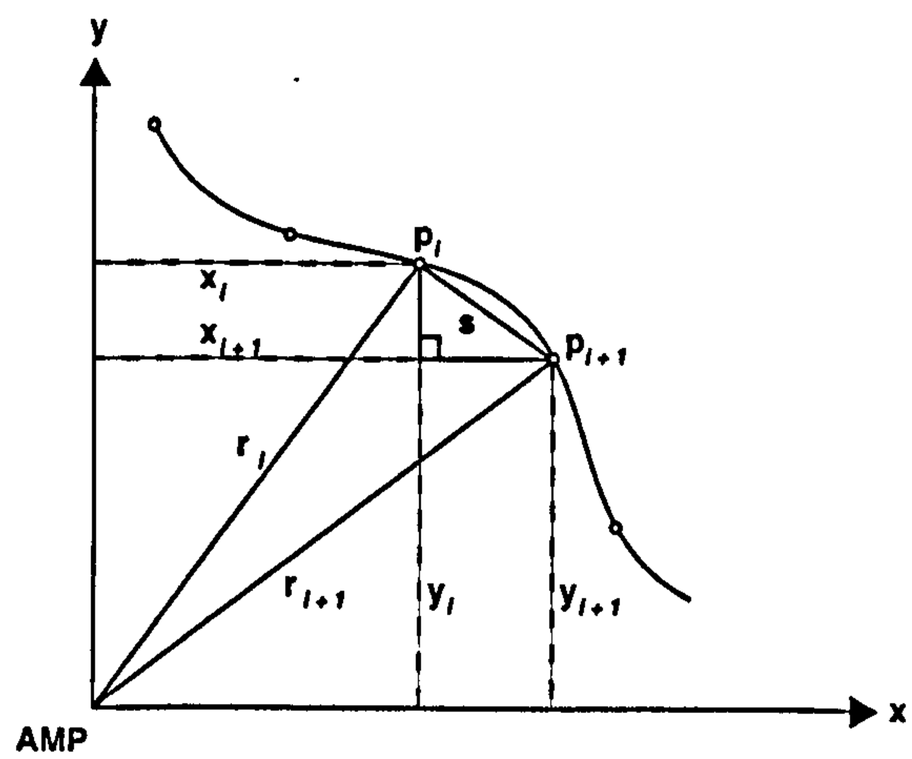
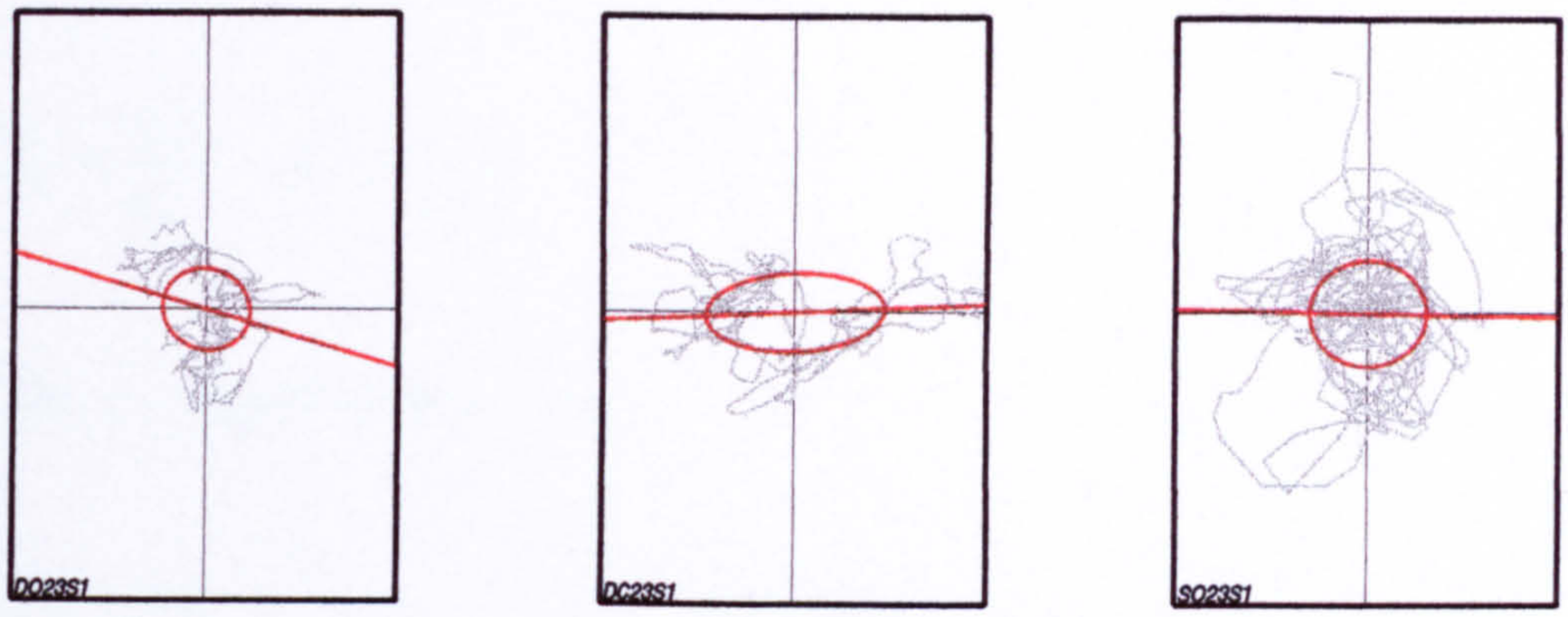


Figure 6.2. Estimation of sway path using trigonometry (adapted from Hufschmidt et al., 1980).



(a) DO (b) DC (c) SO

Figure 6.3. Time series plots of COP position in three stance conditions.

Frequency domain parameters

A signal may be represented in both time and frequency domains. In the frequency domain the time series consists of a series of frequencies possessing specific amplitudes. A trigonometric or Fourier series may be used to describe the frequencies and amplitudes within the signal. The general trigonometric series may be expressed as follows:

$$f_n(x) = \frac{1}{2}a_0 + a_1\cos(x) + \ldots + \frac{1}{2}a_n\cos(nx) + b_1\sin(x) + \ldots + b_{n-1}\sin((n-1)x) \quad (6.3)$$

(Lanczos, 1966)

Using this series the Fourier coefficients ($1/2a_0$, a_k and b_k) of the function are calculated according using the following three equations:

$$\frac{1}{2}a_0 = \frac{1}{n}\sum_{a=0}^{a=2n} f(x_a) \quad (6.4)$$

$$a_k = \frac{1}{n}\sum_{a=0}^{a=2n} f(x_a)\cos(kx_\alpha) \quad (6.5)$$

$$a_k = \frac{1}{n}\sum_{a=0}^{a=2n} f(x_a)\sin(kx_\alpha) \quad (6.6)$$

where:

$$x_\alpha = \frac{\pi}{n}\alpha \ , \quad \alpha = 0....2n$$

$f(x_\alpha)$ = signal value at time x_α

$k = 1....n$

Each Fourier coefficient a_k and b_k, which represent the weightings of the cosine and sine functions respectively, corresponds to a single harmonic within the function. The coefficient $1/2a_0$ is equal to twice the arithmetic mean of the signal in the time domain. The frequency (f_k) and amplitude (c_k) of the 1st to the nth harmonics are calculated using the following formulae:

$$f_k = \frac{k}{T} \tag{6.6}$$

$$c_k = \sqrt{a_k^2 + b_k^2} \tag{6.7}$$

where:

a_k and b_k = the kth Fourier coefficient

c_k = the amplitude of the kth frequency

f_k = the kth frequency

T = the total time of the signal

Power of the signal at each discrete frequency is equal to the square of the amplitude at that frequency (Press, Flannery, Teukosly & Vetterling, 1988) as shown in Equation 6.8.

$$P_k = c_k^2 \tag{6.8}$$

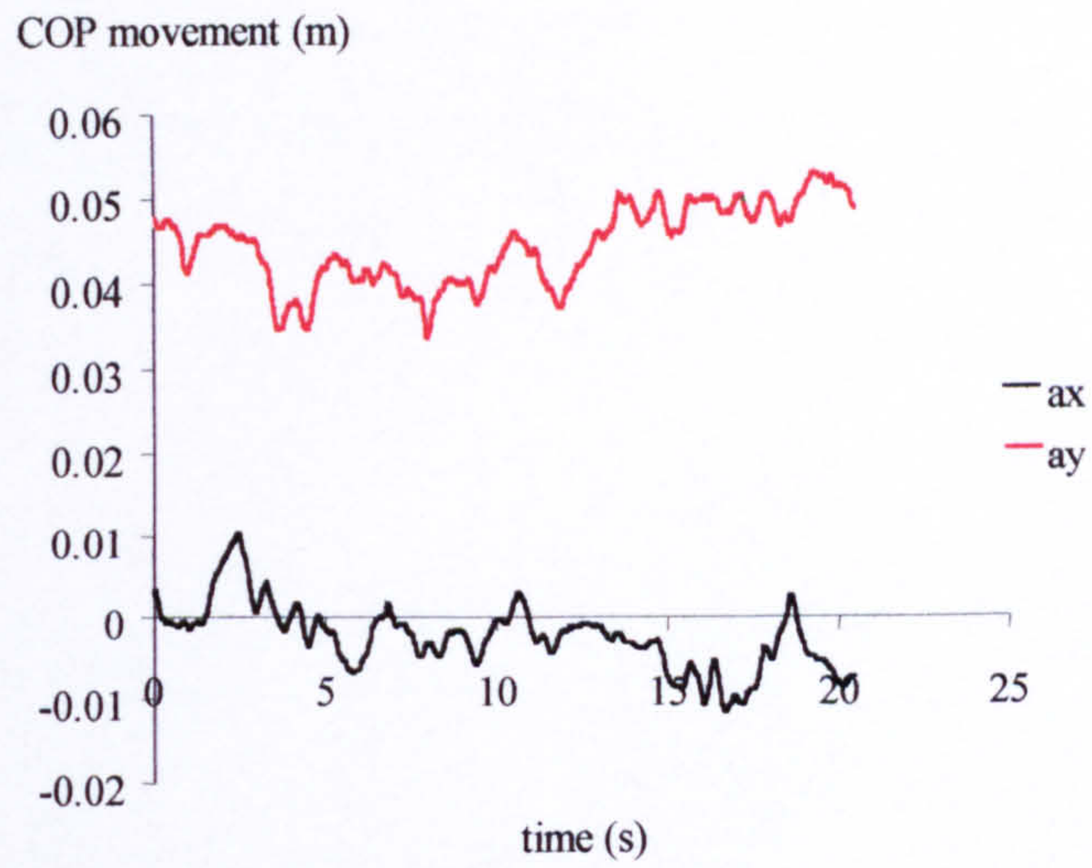
The total signal energy (E_s) may be calculated as the sum of all powers at each discrete frequency excluding 0 Hz and 0.05 Hz (k=0 and k=1):

$$E_s = \sum_{k=2}^{k=k} P_k \qquad (6.9)$$

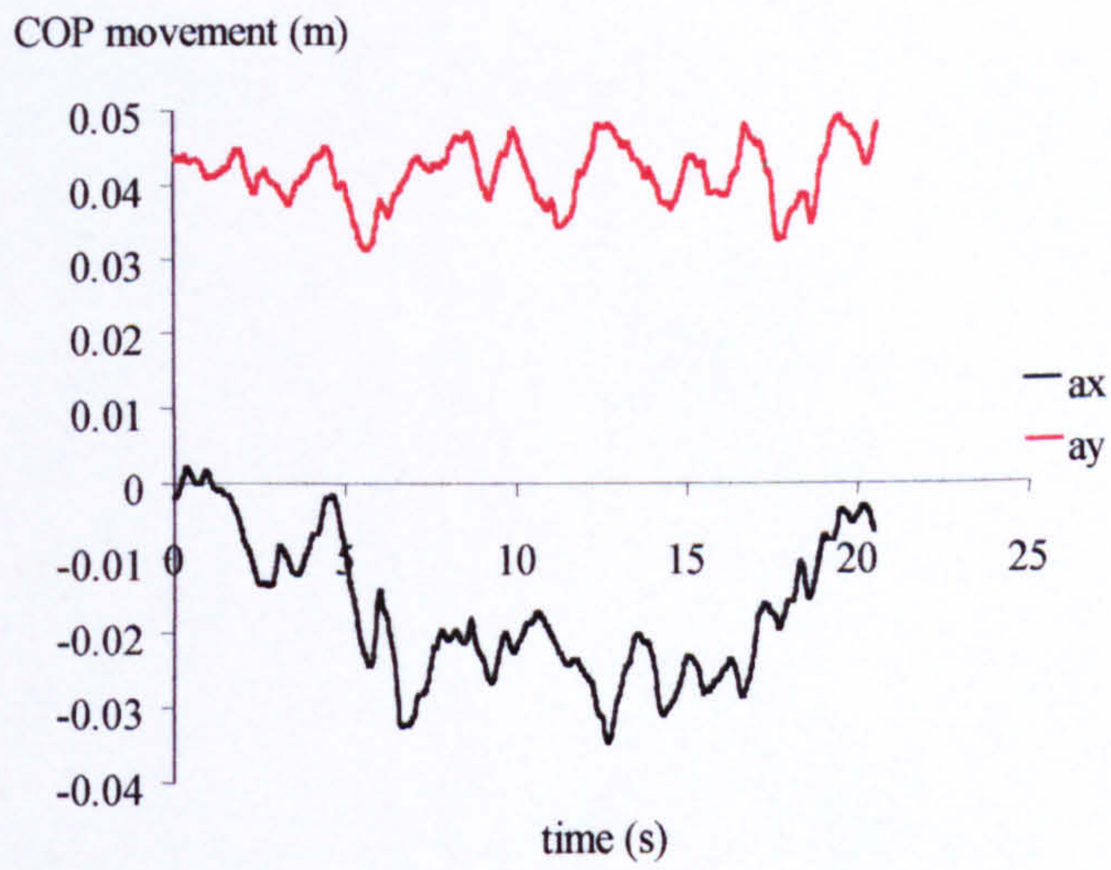
Figure 6.4 indicates the absolute position of the gymnast on the force plate and the movement of the centre of pressure over the 20 s trial. Since only the relative movement of the centre of pressure was of interest in the calculation of postural sway parameters each time series was adjusted to negate the fact that the gymnasts were standing in different absolute locations on the force plate. This was achieved by subtracting the mean value of the time series data from each data point. The adjusted data were multiplied by a Hanning window to reduce the effect spectral leakage. However, the use of the window introduced a new offset, whereby the mean of the time series was no longer zero and therefore a new DC offset value (0th harmonic) was produced. A Fourier transformation was performed on the windowed data series to determine the Fourier coefficients (Equation 6.3). The amplitude and power at each discrete frequency were determined using equations 6.7 and 6.8. Power at the 0th harmonic and the 1st harmonic were removed and not therefore included in the calculations of signal energy. Power at the 0th harmonic (0 Hz) was considered to reflect the DC offset introduced by the window function whilst power at the 1st harmonic (0.05 Hz) represented the period associated with the total time period of 20 s.

In addition, the resultant signal energy of the centre of pressure was calculated to provide a global index of postural steadiness in the frequency domain. Resultant signal energy (E_R) was determined using Equation 6.10:

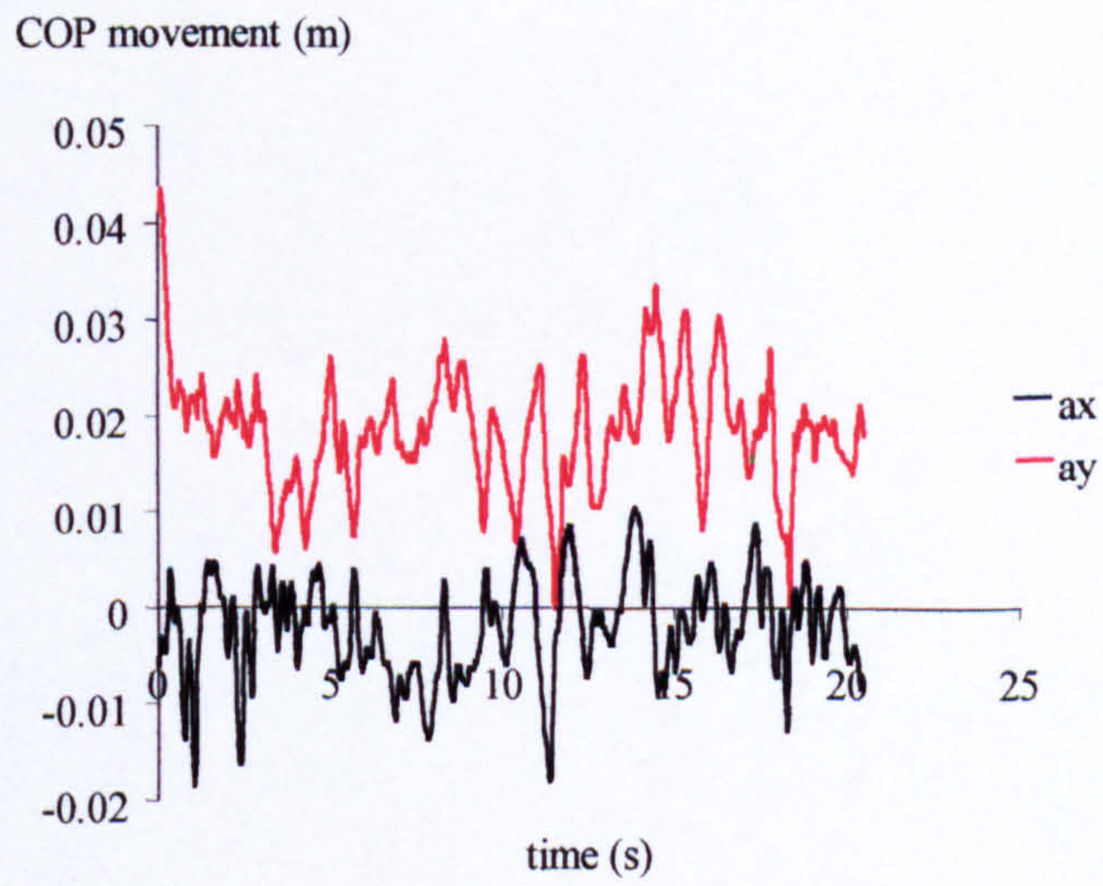
$$E_R = \sqrt{(E_S a_x)^2 + (E_S a_y)^2} \qquad (6.10)$$



(a) DO stance (subject 036)



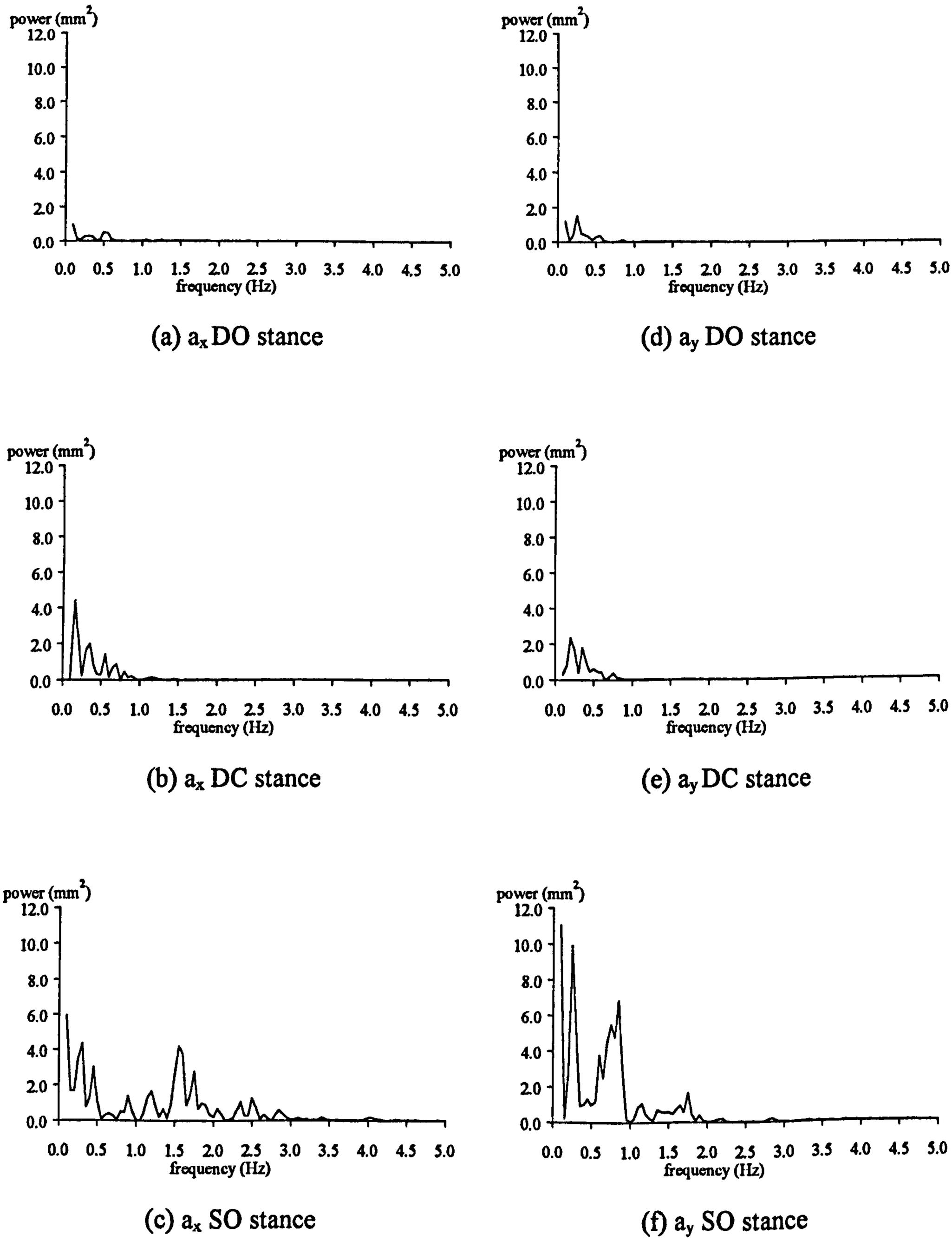
(b) DC stance (subject 036)



(c) SO stance (subject 036)

Figure 6.4. Displacement of the COP during the various stance conditions.

Power spectral density (PSD) plots were produced to provide a visual representation of the signal in the frequency domain. Examples of a PSD plot for each stance condition are provided in Figure 6.5.



(a) a_x DO stance

(d) a_y DO stance

(b) a_x DC stance

(e) a_y DC stance

(c) a_x SO stance

(f) a_y SO stance

Figure 6.5. Power spectral density plots across stance conditions (subject 023).

Balance

A modified version of the Nelson balance test (Johnson & Nelson, 1986 op cit. Kirby, 1991) shown in Figure 6.6 was conducted to provide a composite assessment of static and dynamic balance.

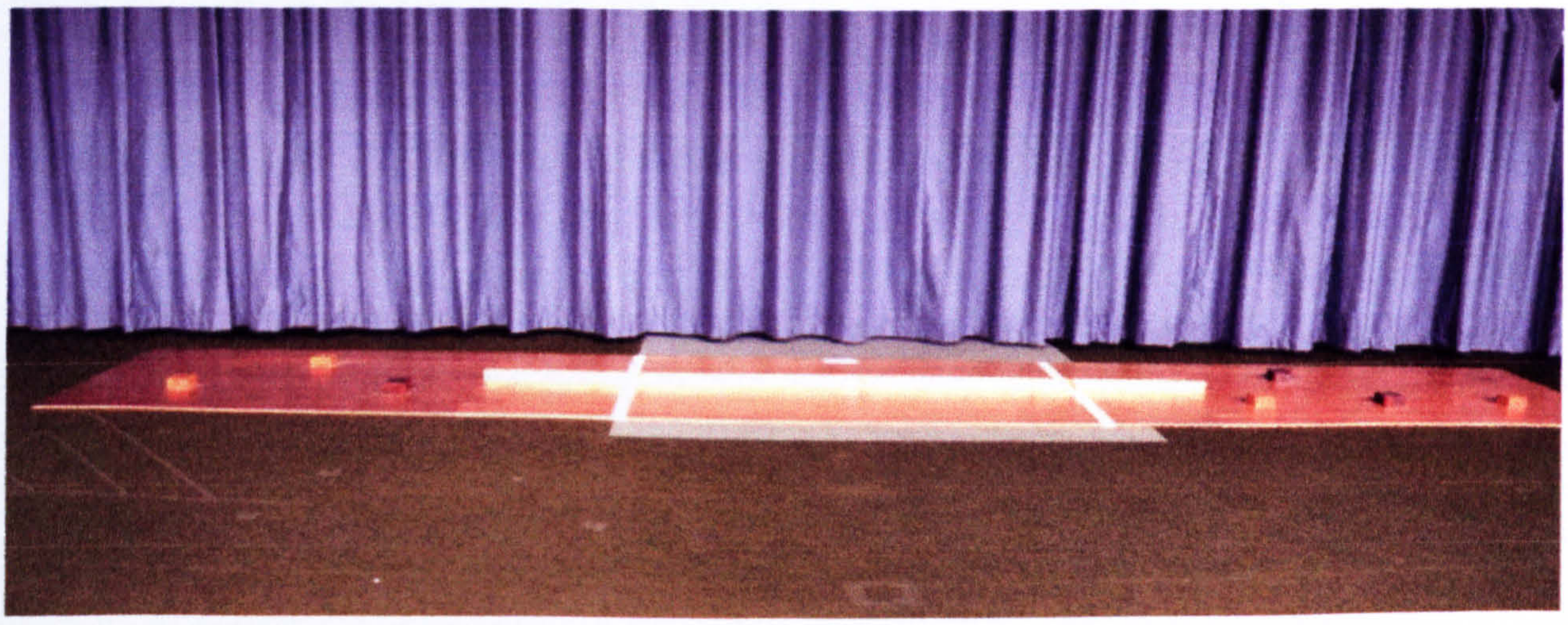


Figure 6.6. The modified Nelson balance test (Johnson & Nelson, 1986 op cit. Kirby, 1991).

Gymnasts were informed that the objective of the test was to complete the task as quickly as possible without making mistakes and that a 5 s time penalty would be imposed for any mistakes and/or falls. The test was timed using a stopwatch and scored to nearest 0.1 s. The assessment was commenced from the end of the apparatus containing four wooden blocks. Timing began as the gymnast placed the ball of the left foot on the first yellow block and attempted to balance for 5 s which was counted aloud by the recorder. If balance was lost the gymnast returned to the block to complete the remainder of the 5 s balance. The gymnast subsequently stepped across the brown blocks as quickly as possible before attempting to balance on the next yellow block. The gymnast initially contacted the balance beam with the right foot and walked across heel to toe. If a mistake was made during the beam walk the gymnast returned to the point at which the mistake/loss of balance occurred and continued with the assessment. The gymnast stepped off the balance beam with the left foot and completed the remaining three blocks stepping across the brown blocks and balancing for 5 s on each yellow block. Timing of the first phase ceased as the gymnast stepped off the final yellow block. The gymnast then turned around and

completed the reverse of the course. Timing restarted as the gymnast placed the ball of the right foot on the first yellow block and ended as the gymnast stepped off the final yellow block. The final score was the time taken to complete both phases with the addition of any imposed time penalties. Prior to the commencement of the test the recorder demonstrated the procedure and each gymnast was given one practice trial for familiarisation. Two attempts were scored with the best score counting after the addition of any time penalties.

Kinaesthesis

Cross-modal matching

The gymnast attained a seated position with the upper body erect and vision of the legs occluded. The gymnast was shown a 'criterion' photograph of a young gymnast maintaining a specific angle of knee flexion (Figure 6.7).

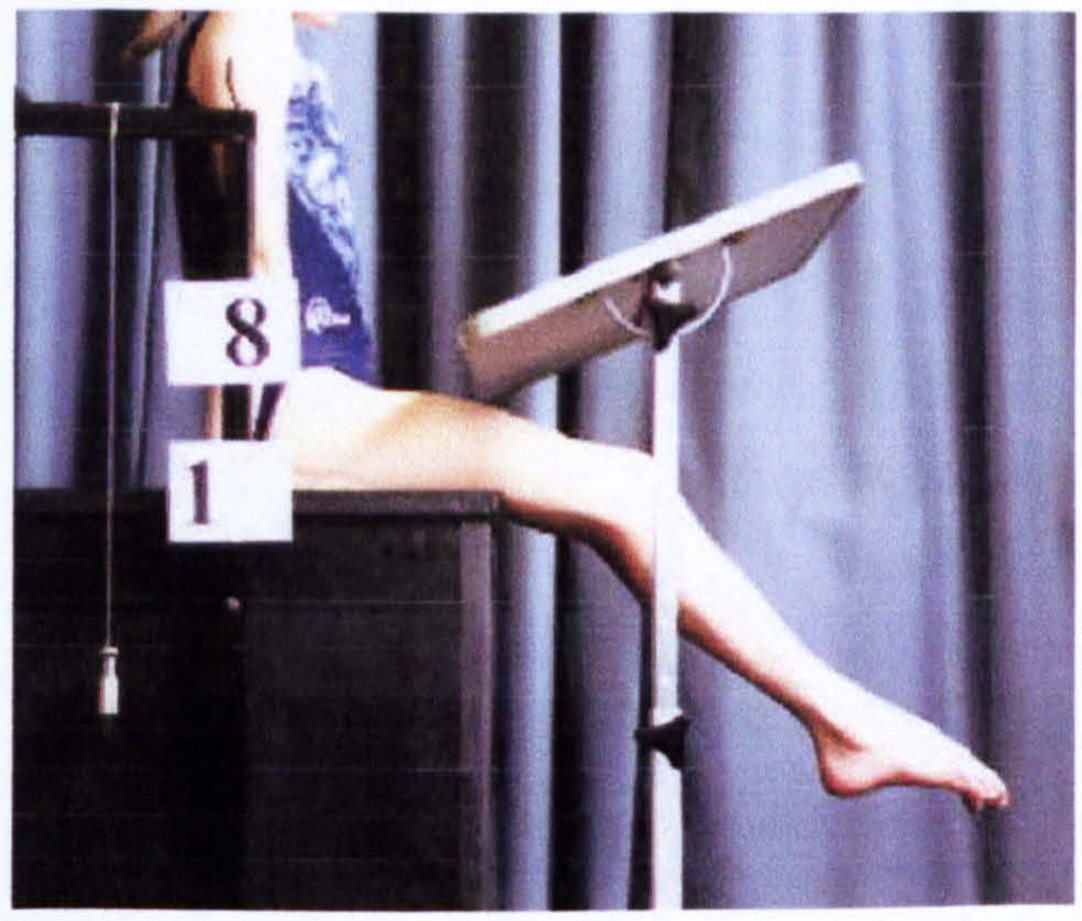
Figure 6.7. The criterion photograph used in the 'matching' task.

While observing the criterion photograph the gymnast was required to 'match' the position shown in the photograph. As the 'criterion angle' was assumed the gymnast was asked to take note of the feeling in the legs as she moved to and held the required configuration. Once the gymnast indicated that she had reproduced the angle a still photograph was taken.

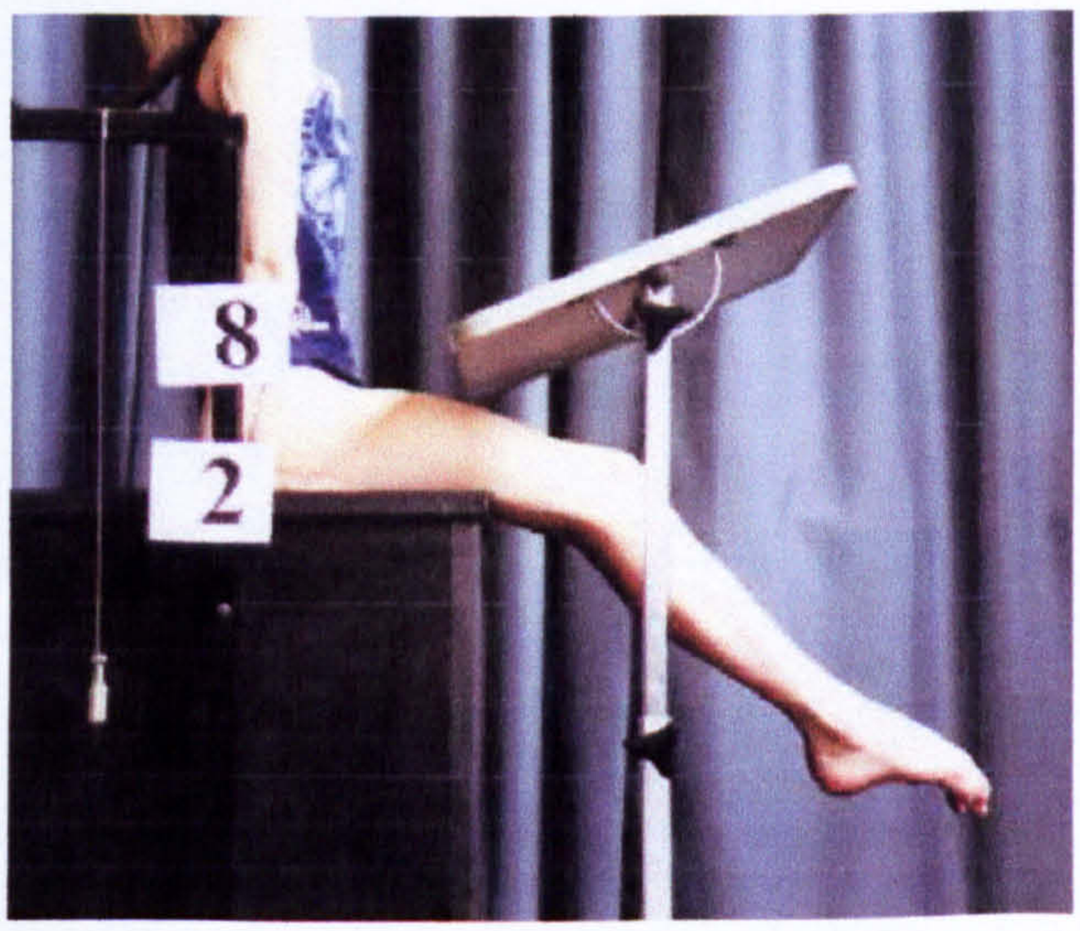
Intra-modal matching

In order to determine how well the gymnast was able to retain kinaesthetic information in the short term memory store the photograph was removed and the gymnast rested in the seated position for 30 s. The gymnast was then asked to reproduce the knee angle she had previously demonstrated using the kinaesthetic information retained from the previous trial. Once the gymnast indicated that she had reproduced the angle a second still photograph was taken. The 30 s interval was appropriate to assess retention of information in the short-term memory store and was in excess of the maximum time for which the visual representation of a target could be stored (Thompson, 1980 op cit. Jeannerod, 1989; Schmidt & Lee, 1999). This procedure was subsequently repeated using a rest period of 180 s to determine the extent to which gymnasts were able to retain kinaesthetic information in the long term memory (Schmidt & Lee, 1999).

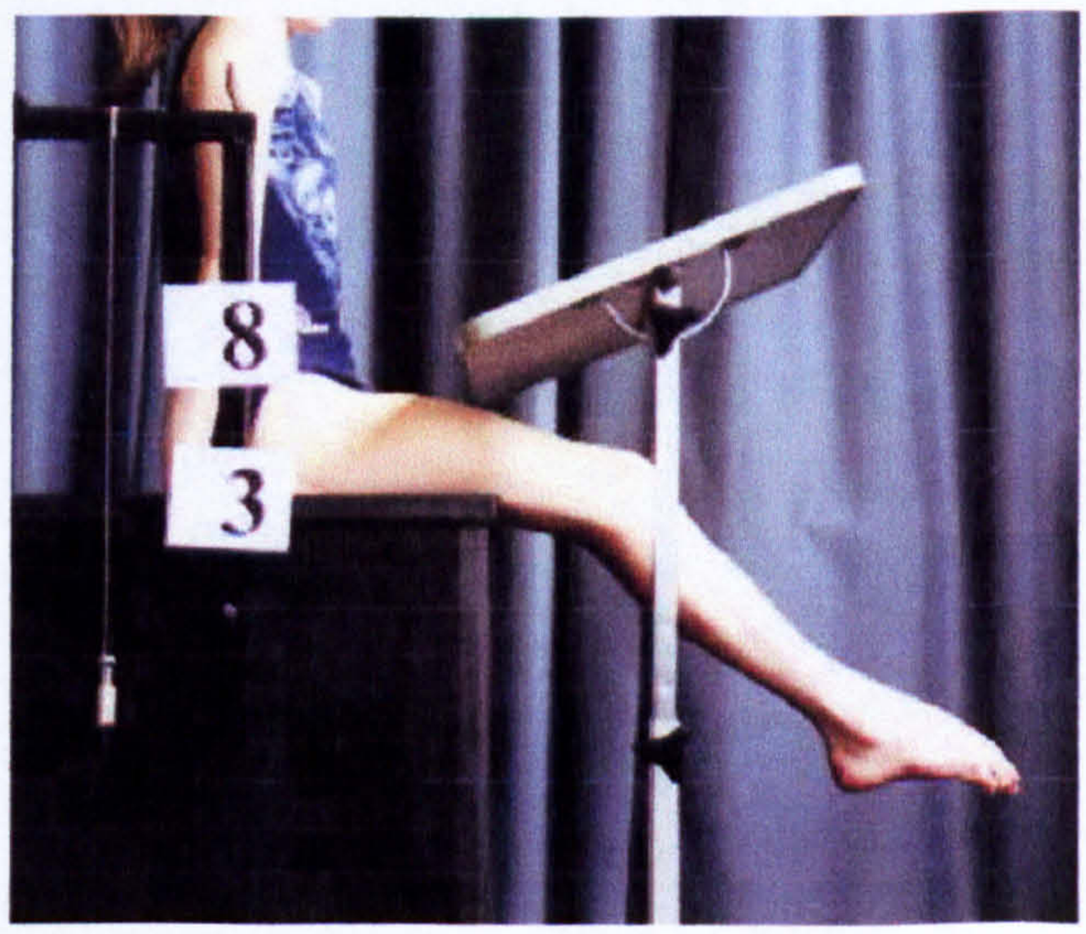
The criterion angle (142°) and the three angles produced by the gymnast were determined using acetate sheets placed over the still photographs. The midline of the shank and thigh segments were traced and the angle of intersection was estimated (Figure 6.8). The precision of this technique was estimated to be 0.42° using the root mean square difference about the mean for 10 estimates of the angle using a single photograph. Three scores were derived to indicate position sense. Firstly, the absolute difference between the angle (with photograph) and the criterion angle provided an estimate of V-K position sense. The absolute difference between the angle (with photograph) and the angle after 30 s rest (no photograph) provided an estimate of the ability to retain kinaesthetic information in the short term memory store. Finally, the absolute difference between the angle (with photograph) and the angle after 180 s rest (no photograph) provided an estimate of the ability to retain kinaesthetic information in the long term memory store.



(a) with photograph



(b) 30s no photograph



(c) 3 minutes no photograph

Figure 6.8. A sequence of photographs showing conditions used in the 'matching' task.

Pointing

Using the apparatus shown in Figure 6.9 the gymnast was seated and given a wooden bar of diameter 20 mm to hold. The seat was then rotated 180° to reveal a similar wooden bar suspended against a black background at one of three selected heights (1.35 m, 1.45 m and 1.55 m). The gymnast was asked to pay particular attention to the height of the bar. The seat was then rotated 180° and the gymnast was asked to stand and raise the bar they were holding against a similar background. The gymnast was specifically instructed to raise the bar to the same height as the suspended bar. The gymnast's perception of the height of the bar was recorded using a scale visible only to the recorder. Each gymnast was given three attempts. Pointing accuracy was estimated as the root mean square difference about the criterion height. Pointing consistency was determined as the root mean square difference about the mean for the three trials.

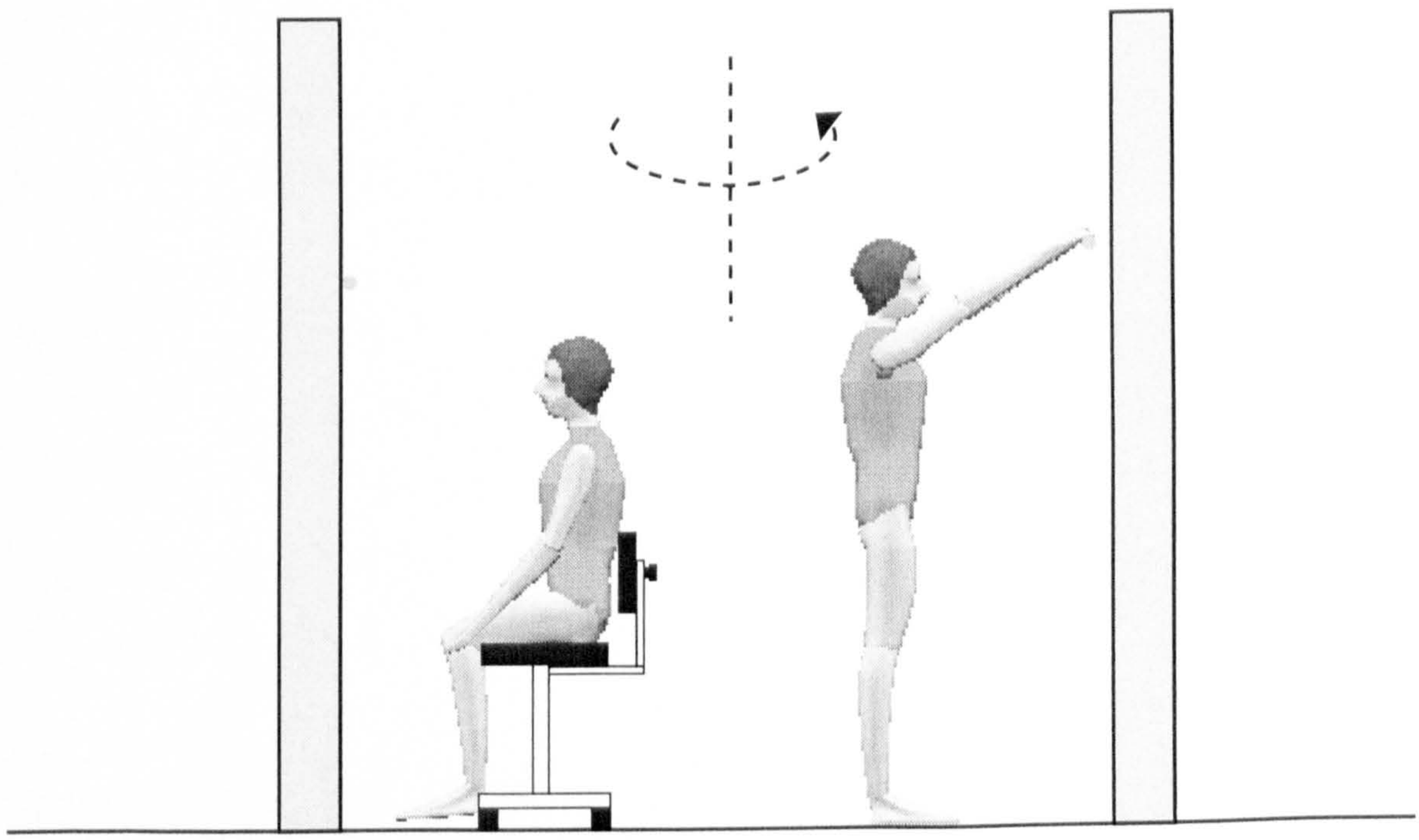


Figure 6.9. The apparatus used in the pointing task.

Perception of force

Each gymnast performed three maximal standing broad jumps beginning with the back of the heels touching a white line as described in Section 5.3. Prior to the final maximal broad jump the recorder asked the gymnast to pay particular attention to the 'feeling' of exerting a maximal effort. Upon completion of the jump the distance was recorded. The

gymnast returned to the starting position with the back of the heels against the line. Half the distance of the final maximal jump was calculated and indicated with a chalk line. The gymnast then moved to a second line on the mat and attempted to jump half the distance of the previous maximum attempt. The accuracy of force perception was expressed as the absolute deviation between the gymnast's attempt to reproduce 50% of the final maximal jump and the calculated value. It was considered necessary to indicate the distance using a chalk line to ensure that the performances of the younger gymnasts were not limited by their inability to conceptualise the required distance.

Perception of rotation

The gymnast was required to stand on a varnished wooden board (1 m square) with the midline of the feet placed adjacent to a thin black line running down the centre of the board (Figure 6.10). With vision occluded using blackened goggles the gymnast was required to complete a 360° turn using small movements of the feet finishing in a stationary standing position with the feet together. The gymnast was then asked to remove one foot while the recorder placed a 300 mm steel ruler adjacent to the medial side of the stationary foot. The angle between the steel ruler and the midline of the board was recorded in degrees using a protractor. Each gymnast was given three attempts. Rotation accuracy was estimated as the root mean square difference about the criterion angle (0°). Rotation consistency was determined as the root mean square difference about the mean score for the three trials.

Figure 6.10. Perception of rotation.

Perception of timing

A single segment computer simulation model of a gymnast performing a giant circle on a single bar (Hiley, 1996, unpublished) was used to assess the gymnast's perception of timing (Figure 6.11). The program required the gymnast to click the mouse button as the model reached the lowest point of the circle (i.e. the point at which the model had completed 180° rotation about the bar). Each gymnast performed ten trials with a score provided after each trial to indicate the deviation from the desired angle. Timing accuracy was estimated as the root mean square difference about the criterion angle (180°). Timing consistency was determined as the root mean square difference about the mean score for the 10 trials.

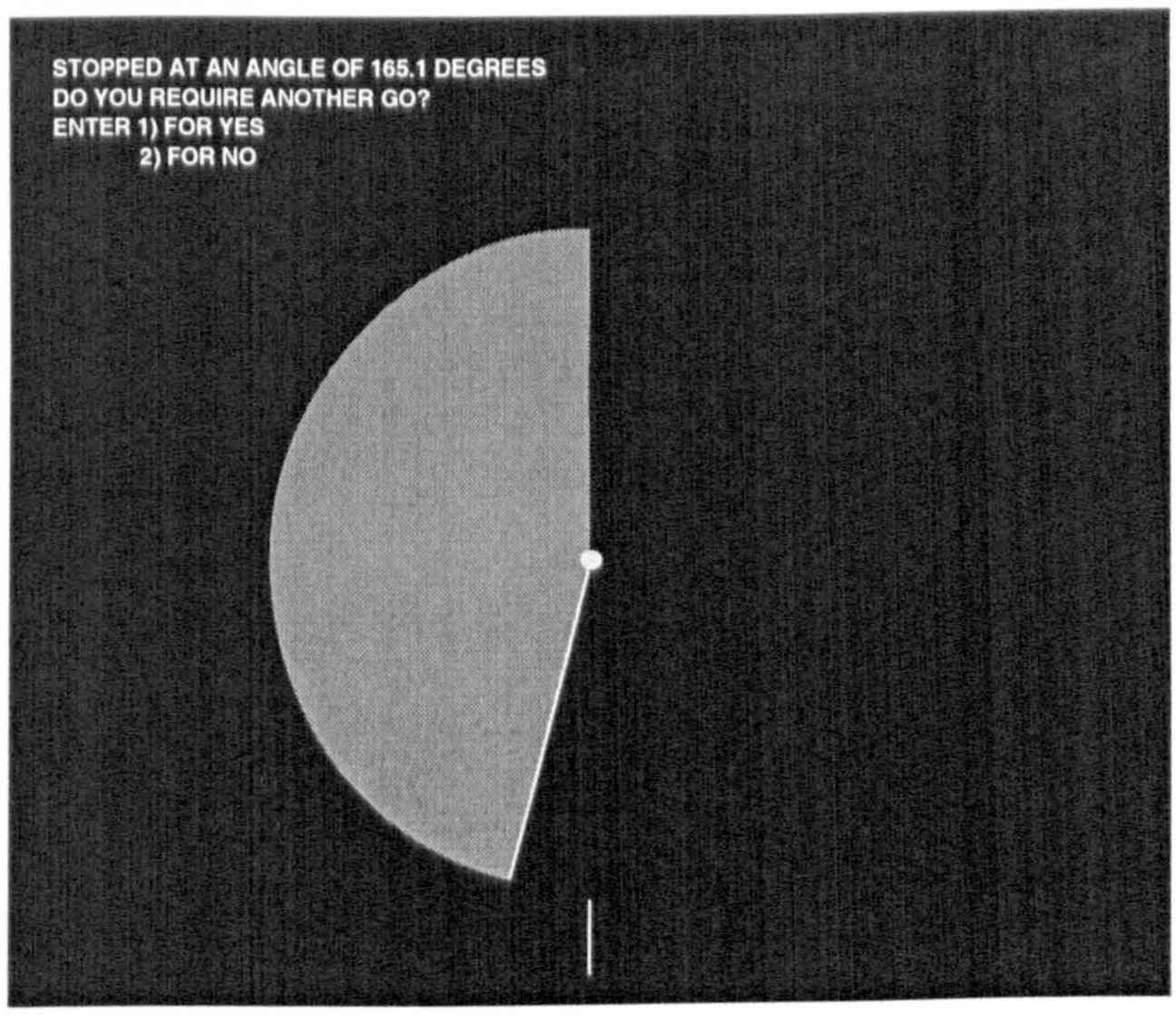


Figure 6.11. Perception of timing.

6.4 RESULTS

6.4.1 RELIABILITY

The test-retest reliability of perceptual-motor variables was estimated using the modified limits of agreement method (Bland & Altman, 1986) as outlined in Section 3.6. To limit the influence of heteroscedastic errors, which were observed in 92% of perceptual-motor

characteristics, the raw data were logarithmically transformed. The mean difference (measurement bias) and standard deviation of the differences (measurement variability) between the logarithmically transformed test and retest data are presented in Table 6.2. For the majority of perceptual-motor variables, estimates of measurement bias and in particular measurement variability were higher than the values reported for the physical talent characteristics (Section 5.4). Indeed, only a single perceptual-motor characteristic (balance) demonstrated adequate reliability according to the limits imposed for the physical variables (measurement bias $\leq$ 0.05 and measurement variability $\leq$ 0.12). The poor test-retest reliability was expected and was considered to reflect the nature of the talent characteristics within the perceptual-motor dimension of performance. However, given the relationship which intuitively exists between perceptual-motor characteristics and future gymnastic success it was considered appropriate to select a single talent characteristic to represent each category based upon face validity and reliability considerations (Helmstadter, 1964 op cit. Laszlo & Bairstow, 1985).

Each condition within the matching task was associated with a high level of measurement variability. The matching task with 180 s delay (m180s) was selected to represent this category. This intra-modal condition (kinaesthetic-kinaesthetic) was speculated to be most closely associated with the demands of skill acquisition in the young female gymnast which emphasise both 'shaping' and the long term retention of kinaesthetic information. For the pointing, rotation and timing tasks, accuracy scores defined by the root mean square difference about the 'criterion point' demonstrated similar and/or lower levels of measurement variability in comparison to consistency scores and were therefore selected as the representative characteristics. The perception of force task, defined as the ability of the gymnast to jump exactly 50% of her maximal broad jump, was both highly variable and demonstrated considerable measurement bias. It was concluded that the current assessment did not adequately assess the ability of the gymnast to perceive and replicate force production and was excluded from the battery. Therefore, in addition to the assessment of balance, the following characteristics were retained; average reaction time, matching 180 s delay, pointing accuracy, rotation accuracy and timing accuracy.

Table 6.2. Test-retest reliability of perceptual-motor variables

	n	systematic bias (log mean difference)	variability (log SDD)	reliability
Nelson balance test	10	-0.018	0.103	✓
Average reaction time	10	-0.206	0.480	®
Matching with photo	10	-0.074	1.281	
Matching 30 s delay	10	0.214	0.981	
Matching 180 s delay	10	0.128	0.958	®
Pointing accuracy	10	0.103	0.569	®
Pointing consistency	10	-0.148	0.879	
Force perception	10	-0.865	1.025	
Rotation accuracy	10	-0.195	0.633	®
Rotation consistency	10	-0.595	1.131	
Timing accuracy	10	-0.079	0.442	®
timing consistency	10	0.043	0.438	

where: ✓ variable demonstrates adequate reliability and ® denotes selection for use within statistical analyses

Previous force platform studies have reported good to moderate test-retest reliability for sway parameters (Thyssen, Brynskov, Jansen & Münster-Swendsen, 1982; Ekdahl et al., 1989; McClenaghan et al., 1994, 1996; Kowalski & DiFabio 1995; Lui & Dawson, 1995; Le Clair & Riach, 1996). Based on these results, the time and frequency-based parameters of postural steadiness derived in the present study were assumed to be reliable.

6.4.2 PHYSICAL TALENT CHARACTERISTICS AND FUTURE GYMNASTIC PERFORMANCE

Descriptive statistics for the perceptual-motor characteristics are presented in Appendix 6.1. With the exception of the three stance conditions for postural sway, the ratio of variables to cases in each category was appropriate to proceed directly with the logistic regression analyses. For the postural sway characteristics the data reduction technique of principal components analysis with varimax rotation was conducted within each stance condition. It was considered pertinent to analyse each condition separately to enhance the parsimony of the principal components solution and to determine whether it was possible for parameters within a single stance to distinguish between future successful and unsuccessful gymnasts.

Principal components analysis

Postural sway

Approximately 69% of the postural sway characteristics across all three stance conditions demonstrated unacceptable levels of positive skewness. A logarithmic transformation was applied to reduce skewness and therefore, a combination of raw and logarithmically transformed variables were included in the principal components analyses. All variables which did not achieve normality upon transformation were excluded. The Bartlett's test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy confirmed that the structure of the data matrices were appropriate to proceed with principal components analyses.

Double leg stance, eyes open (DO)

As shown in Table 6.3, four principal components were derived which accounted for a total cumulative variance of 87.1%. The first component (zdo1) explained 34.4% of the variance in the data and comprised a combination of time and frequency based characteristics relating to the magnitude of sway in a_x and a_y directions and was therefore termed the magnitude of resultant sway motion. The second component (zdo2) was

responsible for explaining 20.3% of the variance in the data and consisted of two frequency characteristics indicating the frequency below which 95% and 99% of the power in the a_x signal was contained. This component was therefore termed the frequency of cumulative power (a_x). Similarly, zdo3 contained similar frequency-based terms relating to the a_y direction and was therefore interpreted to represent the frequency of cumulative power (a_y). The final component (zdo4) was represented by a single term, the natural log of the discrete frequency at which the maximum power of the a_x signal was contained. This component represented 13.5% of the variance and was termed the frequency of maximum power.

Table 6.3. Principal components analysis of postural sway data (DO)

	COMPONENTS			
	zdo1	**zdo2**	**zdo3**	**Zdo4**
Variance explained	**34.4%**	**20.3%**	**18.9%**	**13.5%**
ln max power (a_x)	0.832			
ln signal energy (a_x)	0.934			
ln signal energy (a_y)	0.767			
ln resultant signal energy	0.958			
sway path	0.665			
ln standard deviation (a_x)	0.658			
frequency 95% power (a_x)		0.900		
frequency 99% power (a_x)		0.867		
frequency 95% power (a_y)			0.913	
frequency 99% power (a_y)			0.887	
ln frequency at max power (a_x)				0.764

Double leg stance, eyes closed (DC)

Principal components analysis conducted using sway characteristics obtained from the double leg stance eyes closed condition produced four components each of which

accounted for a similar percentage of variance within the data set (Table 6.4). In combination, the four components accounted for 88.9% of the variance in the data.

Table 6.4. Principal components analysis of postural sway data (DC)

	COMPONENTS			
	zdc1	**zdc2**	**zdc3**	**Zdc4**
variance explained	**24.4%**	**24.3%**	**23.1%**	**19.1%**
ln sway area	0.947			
ln sway path	0.791			
ln standard deviation (a_x)	0.879			
ln standard deviation (a_y)	0.742			
ln signal energy (a_x)		0.720		
ln signal energy (a_y)		0.810		
ln resultant signal energy		0.851		
frequency 95% power (a_x)			0.901	
frequency 99% power (a_x)			0.915	
ln max power (a_x)			-0.745	
ln signal energy (a_x)			-0.604	
frequency 95% power (a_y)				0.890
frequency 99% power (a_y)				0.896

Within this condition, the first two components were clearly interpretable and were defined according to the domain of analysis. The first component (zdc1) comprised the four time-based parameters which indicated the magnitude of COP movement and was therefore interpreted to represent the magnitude of resultant sway motion in the time domain. The second component (zdc2) included characteristics associated with signal energy in the a_x and a_y directions and the resultant signal energy and was therefore interpreted to represent the magnitude of resultant sway motion in the frequency domain. The third component

(zdc3) was less clearly interpretable but was assumed to reflect the distribution of frequencies in the medial-lateral (a_x) direction. Two characteristics relating to the frequency of cumulative power in the a_x direction loaded positively on this component (frequencies below which 95% and 99% of signal power were contained). Two further characteristics, the natural logs of maximum power (a_x) and signal energy (a_x), loaded negatively indicating that these variables decrease as the frequency of cumulative power increases and vice versa. It is speculated that this component may reflect the strategies adopted by gymnasts to maintain steadiness in the DC stance. More specifically it is suggested that gymnasts may control their COP movement by swaying at a low frequency with large power at this distinct frequency or by 'attenuating' this power and introducing higher frequency terms. Signal energy also loaded negatively on this component, however, the loading was low and therefore the contribution of this characteristic remains unclear. The fourth component (zdc4) was more straight forward, consisting of two frequency characteristics indicating the frequency below which 95% and 99% of the power in the a_y signal was contained and was therefore termed the frequency of cumulative power (a_y).

Single leg stance, eyes open (SO)

The final stance condition, single leg stance eyes open, was the least stable stance. The principal components analysis identified four components which accounted for a total cumulative variance of 82.7% in the data (Table 6.5). In a similar manner to the DO stance, the first component (zso1) consisted of both time and frequency-based characteristics. Characteristics representing the frequency of cumulative power in both a_x and a_y directions and total sway path loaded positively on this component. The sign of the loadings indicated that as the frequency below which 99% of the signal power is contained is increased, the length of the sway path of the COP also increases. Therefore, it may be assumed that increases in the magnitude of sway, as denoted by sway path, are associated with a increased power at high frequencies. This component was interpreted to indicate the frequency content of the sway path. The second component (zso2) accounted for 22% of the variance and comprised standard deviations in the a_x and a_y directions respectively and sway area. Given that sway area was defined as the area of an ellipse with vertices of ±1.96 standard deviations in the a_x and a_y directions respectively, the composition of this component was expected and it was termed sway area.

Table 6.5. Principal components analysis of postural sway data (SO)

	COMPONENTS			
	zso1	**zso2**	**zso3**	**zso4**
variance explained	**22.3%**	**22.0%**	**21.4%**	**17.0%**
ln frequency 95% power (a_x)	0.898			
ln frequency 99% power (a_x)	0.786			
ln frequency 99% power (a_y)	0.612			
sway path	0.626			
ln sway area		0.930		
ln standard deviation (a_x)		0.940		
standard deviation (a_y)		0.737		
ln frequency at max power (a_y)			0.899	
ln signal energy (a_y)			0.875	
ln resultant signal energy			0.697	
ln signal energy (a_x)				0.922
ln resultant signal energy				0.621

The third and fourth components, zso3 and zso4 consisted exclusively of frequency based characteristics and accounted for 21.4% and 17.0% of the variance in the data. Component zso3 comprised signal energy in the a_x direction and resultant signal energy and was therefore termed 'signal energy a_x' similarly component zso4 consisted of signal energy in the a_y directions and resultant signal energy and was termed 'signal energy a_y'. Given that resultant signal energy is derived from the components of signal energy in the anterior-posterior and medial-lateral directions this loading pattern was in line with expectations. An additional component, the frequency at which maximum power was contained in the a_x direction, also demonstrated a positive loading on zso3 which indicated that a greater signal energy in the medial-lateral direction was associated with increase in the frequency of maximum power. The loading of this characteristic was expected and

indicated that a greater signal energy in the a_x direction was closely associated with large oscillations towards the higher frequency end of the spectrum.

Logistic regression analysis

Logistic regression analysis was employed using a hierarchical procedure to examine the extent to which perceptual-motor characteristics were able to distinguish between gymnasts defined as successful or unsuccessful on the basis of their future performance. To control for the age differences between the groups of successful and unsuccessful gymnasts, the entry of decimal age was 'forced' into the regression model in the first block. As previously reported, the inclusion of decimal age as the sole independent variable was associated with a significant reduction in the log likelihood of 17.2% (model $\chi^2 = 7.425$, $p<0.006$) but resulted in a relatively poor model fit (R^2_L of 0.172). The index of predictive efficiency ($\lambda = 0.333$, $p<0.074$) indicated that classification errors were reduced by approximately one third when decimal age alone was included in the regression model. Given the non-significant reduction in predictive efficiency associated with standardised decimal age it was hypothesised that the inclusion of perceptual-motor variables would enhance classification accuracy.

To test this hypothesis, a series of regression models were produced within each category of perceptual-motor characteristics. For each regression model, the independent variables in block two were entered using stepwise entry procedures. Tolerance values across the range of perceptual-motor characteristics were estimated using linear regression analyses with decimal age included as an additional independent variable in each category. The range of tolerance values for the perceptual-motor characteristics was 0.315-0.982. All values were above the critical value of 0.20 suggested by Menard (1995) which indicated an acceptable level of multicollinearity. The contribution of perceptual-motor characteristics was expressed in terms of the model fit (R^2_L) and the predictive efficiency (λ). Moreover, the contribution of the perceptual-motor characteristics over and above that of decimal age was estimated by considering the reduction in the log likelihood (-2*LL) associated with the stepwise entry of the perceptual-motor characteristics within block two (block χ^2).

Postural sway

For the majority of perceptual-motor categories identical regression models were produced using forwards and backwards stepwise regression models and therefore only a single regression equation will be presented. However, for two stance conditions (postural sway DO and DC) the equations varied according to the method by which the variables were entered into the regression model. These differences may be expected in light of the different criteria employed by forwards and backwards stepwise entry methods to select and/or eliminate independent variables into/from the regression equation. In forwards stepwise estimation methods the variable most correlated with the dependent variable is initially entered into the regression model. Additional variables are entered based on the computation of partial correlation coefficients. These coefficients determine which independent variable is able to explain the largest amount of the unexplained variance. Each time a new variable is added to the regression model the contribution of the variables already contained in the model is re-estimated. If the contribution of a variable is not significant, given the presence of the new variable, it is removed from the regression equation. This process is repeated until no further variables qualify for entry into the model. In contrast, backward elimination starts by including all variables in the regression equation and examines the contribution of each variable in terms of unique variance. Those variables which do not make a significant contribution are removed and the model is recalculated. This process continues until no further variables can be removed from the model (Hair et al., 1995). Therefore, it is possible that if several variables are highly correlated a particular variable may be entered first in forwards stepwise estimation but may explain little in terms of unique variance and therefore be may be removed in the early stages of the backwards elimination procedure.

Double leg stance, eyes open (DO)

Forwards stepwise regression model

The regression equation presented below was produced using the forwards stepwise entry method:

$$\text{Logit(successful)} = 1.3736(\text{zdecage}) - 1.2585(\text{zdo1}) - 0.7467$$

A single component, zdo1, was included in the regression model which was interpreted to represent the magnitude of resultant sway motion. The negative coefficient associated with this component indicated that within the present sample of young female gymnasts future success in gymnastics was associated with a smaller amount of postural sway during a double leg stance with the eyes open. While it is acknowledged that the centre of pressure is not synonymous with the mass centre, the COP adequately represents the location of the mass centre during quiet stance (Hasan et al., 1996a; Riley et al., 1990 op cit. Davis & Grabiner, 1996; Allum, 1990). It was therefore concluded that successful gymnasts exhibited greater postural steadiness in this particular stance condition. The model fit ($R^2_L = 0.245$) was moderate, with the reduction in the log likelihood associated with the regression model significant at the 1% level (model $\chi^2 = 10.608$, $p<0.005$). However, the 7.4% reduction in the log likelihood for block two which contained the sway components, did not attain statistical significance at the 5% level (block $\chi^2 = 3.183$, $p = 0.074$). Therefore, it may be concluded that in terms of model fit, the components derived from the double leg stance with the eyes open are of limited value.

Table 6.6. Classification table for the logistic regression model including postural sway (DO) components (forwards stepwise)

	Unsuccessful	successful	correct
Unsuccessful	19	2	90.5%
Successful	4	8	66.7%
		overall	81.8%

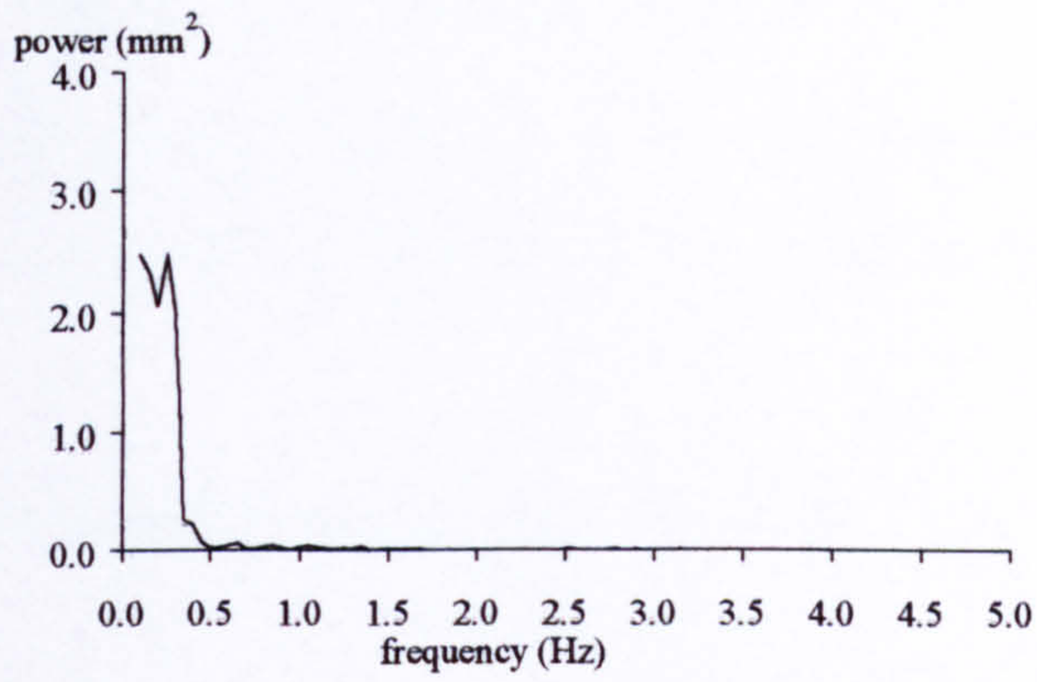
As shown in Table 6.6 the classification accuracy of the model was good ($\lambda = 0.500$, $p=0.015$) indicating that the model was able to reduce errors in the prediction of group membership by 50%. While this reduction was statistically significant at the 5% level, the regression model including zdo1 was unable to classify successful gymnasts to a greater level of accuracy than could be achieved using decimal age as the sole independent variable. The improvement in classification of the block containing the DO components was limited to two additional control subjects.

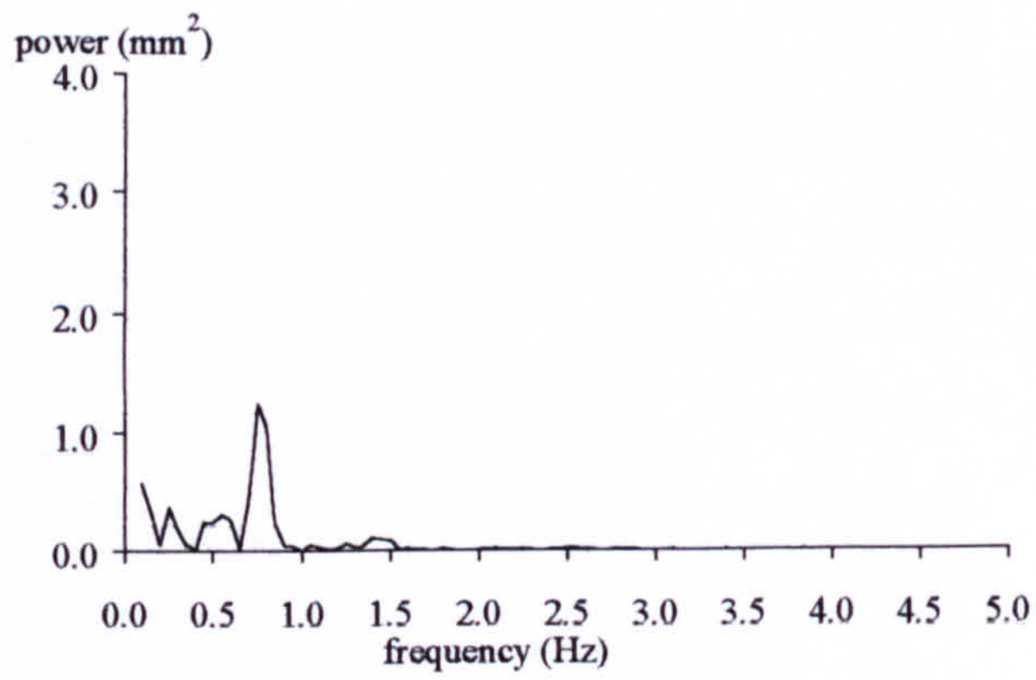
Backwards elimination model

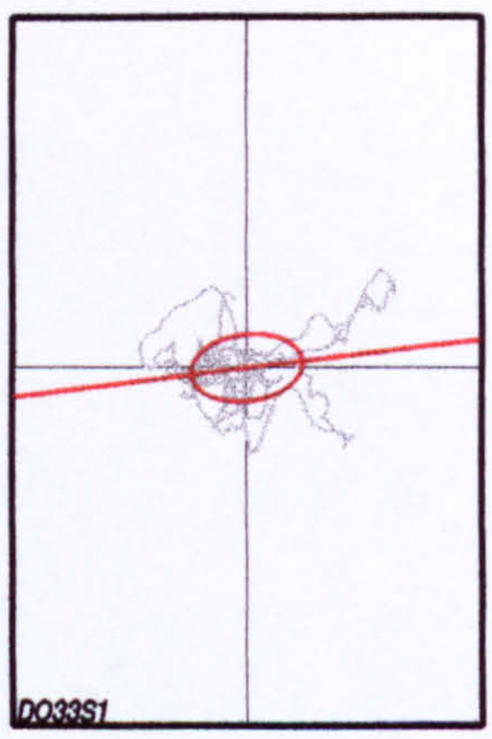
An alternative regression model was produced using the backwards elimination procedure as shown below:

$$\text{Logit(successful)} = 1.3754(\text{zdecage}) - 1.4684(\text{zdo1}) + 0.7602(\text{zdo2}) - 0.6685(\text{zdo3}) - 0.8376$$

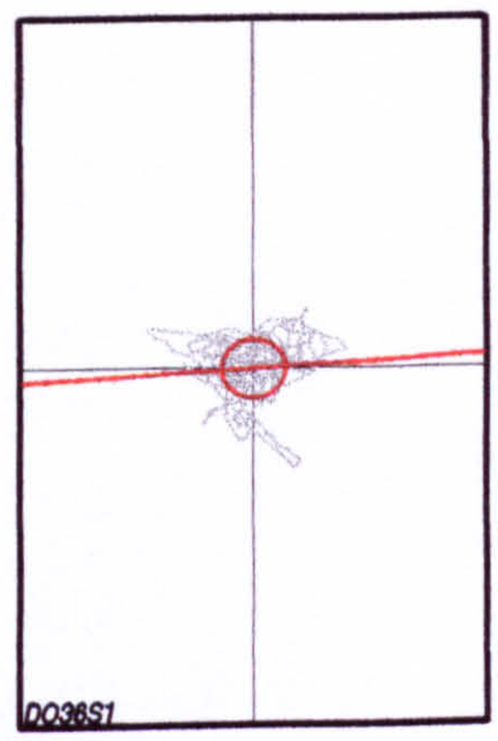
Once again, the coefficient associated with the magnitude of resultant sway motion (zdo1) was negative indicating that success was associated with greater postural steadiness. Similarly the coefficient associated with zdo3 was negative signalling that 95% and 99% of the signal power of the more successful gymnasts in the anterior-posterior (a_y) direction was contained at a lower maximum frequency. This was interpreted to indicate that a greater amount of the signal energy was contained in the lower part of the frequency spectrum. In contrast, zdo2 was associated with a positive coefficient which suggests that in comparison to their less successful peers, the signal power of successful gymnasts in the medial-lateral (a_x) direction was located towards the higher frequency part of the spectrum. Therefore, it appears that the successful gymnasts in the present study were characterised by higher frequency sway in the medial-lateral direction but lower frequency sway in the anterior-posterior direction. The reasons for this observation are not clear. They may be a function of the small sample size but may alternatively indicate the strategy adopted by successful gymnasts to maintain postural steadiness. Support for the latter may be derived from the observation that the mean standard deviation of sway in the medial-lateral direction was slightly smaller for the successful gymnasts (4.20 ± 1.45) compared to the unsuccessful gymnasts (4.29 ± 2.36). Therefore, it appears that while they are oscillating at a higher frequency in the medial-lateral direction, successful gymnasts are swaying at a reduced amplitude. Representative power spectral density plots of the COP in the medial-lateral and accompanying stabilograms for an unsuccessful and successful gymnast are presented in Figure 6.12. One possible explanation for this observation is that the successful gymnasts may have greater acuity to perceive sway and may therefore be able to detect movements of the mass centre more rapidly than their less successful peers.







(a) unsuccessful gymnast (033)



(a) successful gymnast (036)

Figure 6.12. Power spectral density plots (a_x) and stabilograms for (a) unsuccessful and (b) successful gymnasts (DO stance).

The regression model produced using the backwards entry procedure was slightly superior to the forwards model in terms of model fit ($R^2_L = 0.322$). However, the 15% reduction in the log likelihood associated with sway components did not attain statistical significance at the 5% level (block $\chi^2 = 6.495$, p=0.090). The model produced using backwards elimination was also superior in terms of classification accuracy (λ =0.667, p=0.002) with a total of four gymnasts mis-classified (Table 6.7).

Table 6.7. Classification table for the logistic regression model including postural sway (DO) components (backwards elimination)

	Unsuccessful	successful	correct
unsuccessful	20	1	95.2%
successful	3	9	75.0%
		overall	87.9%

Double Leg Stance, Eyes Closed (DC)

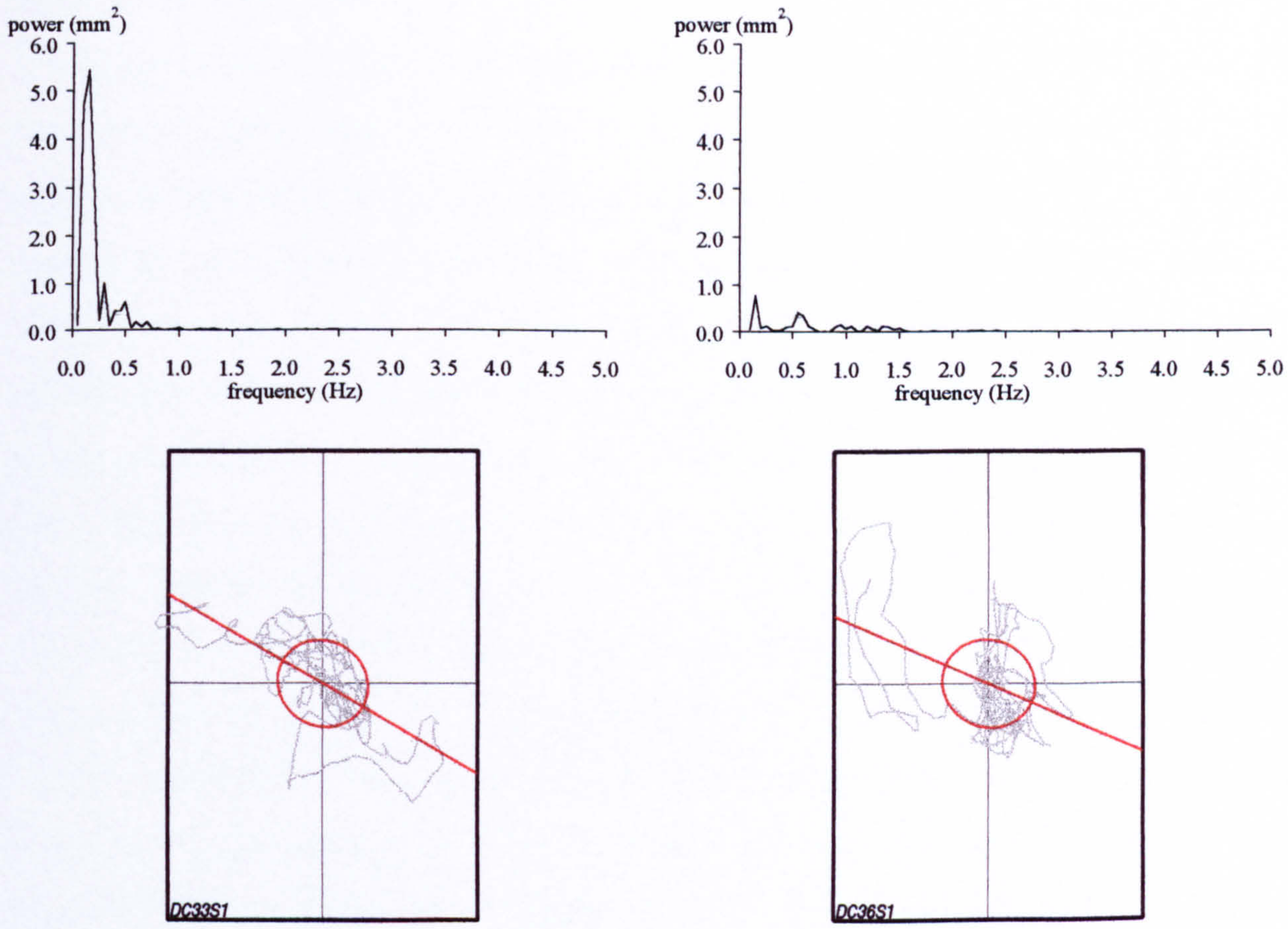
Once again, different regression equations were obtained according to method in which the independent variables were entered into the regression model.

Forwards stepwise regression model

$$\text{Logit(successful)} = 0.9820(\text{zdecage}) + 1.0843(\text{zdc3}) - 0.8517$$

The component zdc3 was included in the regression model and was associated with a positive coefficient indicating that a particular frequency distribution in the medial-lateral (a_x) direction was associated with successful gymnastic performance. According to the positive regression coefficient and the component loadings presented in Table 6.4 the successful gymnasts had a smaller maximum power but their power was distributed more towards the higher end of the frequency spectrum. This is in line with the results of the backwards elimination model produced for the DO stance and provides further support for the supposition that in double leg stances, irrespective of vision, successful gymnasts use a strategy and control postural steadiness which involves high frequency components. However, in contrast to the results of the DO stance, the mean standard deviation of successful gymnasts in the medial-lateral direction (a_x) (6.65 ± 3.57) was greater than that of their less successful peers (5.59 ± 2.62). This result is illustrated in the power spectral density plots and accompanying stabilograms for the unsuccessful and successful gymnasts presented in Figure 6.13. The extent of the increase in the standard deviation in the a_x observed for successful gymnasts was surprising given that the previous studies have consistently reported that the effect of eye closure is most pronounced upon postural sway in the anterior-posterior direction (Hayes et al., 1984; Era & Heikinnen, 1985; Hufschmidt et al., 1980; Lucy & Hayes, 1980).

The fit of the forwards stepwise regression model was moderate ($R^2_L = 0.271$). The reduction in the log likelihood attained by the model was statistically significant at the 1% level (model $\chi^2 = 11.739$, $p=0.003$).



(a) unsuccessful gymnast (033) (b) successful gymnast (036)

Figure 6.13. Power spectral density plots (a_x) and stabilograms for (a) unsuccessful and (b) successful gymnasts (DC stance).

The 10% reduction in the log likelihood by the block containing the DC sway components was significant at the 5% level (block $\chi^2 = 4.314$, p=0.038). As shown in Table 6.8, the classification accuracy of the model was acceptable with a total of seven gymnasts mis-classified which corresponded to a moderate value for Lambda (λ =0.417, p=0.035).

Table 6.8. Classification table for the logistic regression model including postural sway (DC) components (forwards stepwise)

	Unsuccessful	Successful	correct
unsuccessful	18	3	85.7%
successful	4	8	66.7%
		Overall	78.8%

Backwards elimination model

As expected, the regression model produced using the backwards elimination method contained a greater number of components. It was interesting to observe that the component included in the forward stepwise regression model, zdc3, was the first and only component to be excluded in this model. As previously suggested this may be a function of the amounts of common and unique variance explained by each component. Logistic regression models were performed using various subsets of the DC components. For all subsets containing two or more of components dc1, dc2 and dc3, one of these components was excluded in the first stage of the backwards stepwise regression model. It was therefore assumed that a large proportion of the explained variance of these components was shared variance, which was confirmed by assessing the collinearity of these variables using multiple linear regression. Therefore, when zdc3 was entered first using forward stepwise estimation it was responsible for the greatest change in the log likelihood. However, a large proportion of this 'variance' was in fact shared and zdc3 was only responsible for a small amount of 'unique' variance and was therefore the first variable to be excluded using the backwards elimination procedure.

$$\text{Logit(successful)} = 1.1227(\text{zdecage}) + 1.2572(\text{zdc1}) - 2.1740(\text{zdc2}) - 0.8891(\text{zdc4}) - 0.7928$$

Examination of the regression coefficients revealed that successful gymnasts could be distinguished from less successful gymnasts on the basis of a larger magnitude of resultant sway motion in the time domain (dc1), a smaller resultant signal energy (dc2) and a lower frequency of total power in the anterior-posterior direction (dc4). The reasons why larger sway in the time domain is associated with successful performances is not clear however, this observation may be related to the strategy successful gymnasts are adopting to maintain postural steadiness in the medial-lateral direction.

The fit of the model obtained using backwards elimination was slightly better than the forward regression model in terms of model fit ($R^2_L = 0.366$, block $\chi^2 = 8.401$, $p=0.038$), however, in terms of classification accuracy there were no differences between models. Therefore, until the strategies of gymnasts are more clearly understood it is recommended that for prediction purposes the forwards stepwise regression model is used.

Single leg stance, eyes open (SO)

The logistic regression analysis including the sway characteristics derived from the single leg stance produced an identical regression equation irrespective of whether forwards stepwise or backwards elimination methods were used. As shown in the equation below a single component (zsol) was included in the model which combined information from the frequency and time domains. Specifically, this component was associated with the cumulative distribution of frequencies and total excursion of COP in the time domain. The negative coefficient associated with zsol was expected and indicated that success in gymnastics was associated with a smaller movement of the centre of pressure which was achieved using lower frequency oscillations.

$$\text{Logit(successful)} = 1.0522(\text{zdecage}) - 1.8805(\text{zsol}) - 1.0082$$

The fit of regression model was moderate (R^2_L = 0.271) and the reductions in the log likelihood attained by both the model (model χ^2=13.96, p=0.001) and the block containing zsol (block χ^2= 6.535, p = 0.011) were significant at the 1% and 5% levels respectively. The classification accuracy was moderate with six gymnasts mis-classified (Table 6.9). The Lambda value (λ =0.417, p=0.035) indicated that the total regression model reduced the errors in prediction by over 40%.

Table 6.9. Classification table for the logistic regression model including postural sway (SO) components

	Unsuccessful	Successful	correct
unsuccessful	18	3	85.7%
successful	3	9	66.7%
		Overall	78.8%

Balance

A modified version of the Nelson balance test was used as a composite assessment of static and dynamic components of balance and was scored according to the time gymnasts

required to complete the task after all time penalties were added. Therefore, the negative coefficient associated with balance in the regression equation below indicates that gymnastic success was associated with superior functional balance (i.e. the successful gymnasts completed the task more quickly):

$$\text{Logit(successful)} = 0.9415(\text{zdecage}) - 0.7261(\text{zbalance}) - 0.7343$$

The model fit was poor/moderate ($R^2_L = 0.223$) and the inclusion of balance did not reduce the log likelihood by a significant amount (block $\chi^2 = 2.226$ [5.1%], p=0.136). In addition, the classification accuracy of the model was poor (λ =0.333, p=0.074) with no further reduction in prediction errors above the model which included decimal age as the single independent variable (Table 6.10).

Table 6.10. Classification table for the logistic regression model including dynamic balance (forwards stepwise)

	Unsuccessful	Successful	correct
Unsuccessful	18	3	85.7%
Successful	5	7	58.3%
		overall	75.8%

This result was surprising given the intuitive importance of balance to performance in Women's Artistic Gymnastics and previous studies which have indicated a relationship between functional balance and skill level in young female gymnasts (Peltenburg et al., 1982).

Kinaesthetic characteristics

The results of the logistic regression analysis suggested that three components of kinaesthesis contributed to distinguish between successful and unsuccessful gymnasts. However, examination of the regression equation presented below raised doubts concerning the validity of this model.

$$\text{Logit(successful)} = 0.4244(\text{zdecage}) + 1.4989(\text{zpointacc}) - 1.9393(\text{ztimacc}) + 1.5074(\text{zlnm180}) - 1.2255$$

Pointing accuracy, assessed in terms of the root mean square difference (RMSD) between the gymnast's first attempt and the target height, was associated with a positive regression coefficient which indicates that the probability of achieving future success in gymnastics is associated with less accurate performances in the pointing task. Similarly, m180s which was assessed the gymnast's ability to reproduce a previously adopted knee angle after a delay of 180 s, was scored as the absolute deviation of the knee angle assumed by the gymnast from the criterion angle. It was expected that in contrast to their less successful peers, successful gymnasts would be able to more accurately replicate the previously adopted knee angle. However, the positive coefficient associated with m180s suggested that the probability of future gymnastic success was associated with less accurate performances in this intra-model task.

These apparent anomalies were interpreted to be a function of the poor reliability of the perceptual-motor characteristics (Section 6.1). Specifically, the errors associated with the measurement of these characteristics were likely to be in excess of the differences between successful and unsuccessful gymnasts (effect size). In light of these results the decision to select the most reliable test to represent each category of perceptual-motor characteristics irrespective of the absolute reliability was questioned. A more conservative threshold was established for reliability with the maximum acceptable measurement variability set to 0.50. As a result, timing accuracy (ztimacc) was the only kinaesthetic characteristic deemed to have adequate reliability and was therefore the only characteristic included in the revised logistic regression model:

$$\text{Logit(successful)} = 1.0386(\text{zdecage}) - 1.0607(\text{ztimacc}) - 0.8417$$

Once again, timing accuracy was associated with a negative coefficient, which was consistent with the expectation that future success in gymnastics is associated with a more accurate perception of timing. The fit of the revised model was moderate ($R^2_L = 0.273$). The inclusion of timing accuracy in the second block of the model resulted in a reduction

in the likelihood ratio of 10.1% which was significant at the 5% level (block $\chi^2 = 4.375$, p=0.037). Moreover, Table 6.11 indicated that the classification accuracy was improved (λ =0.583, p=0.006).

Table 6.11. Classification table for the logistic regression model including timing accuracy

	Unsuccessful	successful	correct
Unsuccessful	20	1	95.2%
Successful	4	8	66.7%
		overall	84.9%

In comparison to the 'constant only' model, the prediction errors were reduced by almost 60% which according to the d statistic was significant at the 1% level (p<0.006). These results indicate that timing is a potentially important talent characteristic, which can be measured with acceptable reliability using a simple field test.

Average reaction time

For each gymnast the average reaction time across the three isometric tasks was determined. In computing the average value, any reaction times less than 100 ms which was considered to be the minimum possible to achieve were excluded (Schmidt & Lee, 1999). In addition, any trials in which the gymnast clearly did not react to the audio signal were also excluded. Following the forced entry of standardised decimal age, the standardised average reaction time was considered for inclusion in the model using stepwise procedures. However, the change in the log likelihood (-2*LL) did not attain statistical significance at the 20% level and therefore this characteristic was not included in the model. The final model was therefore identical to that reported above when decimal age was included as the sole independent variable.

Logistic regression analysis (summary perceptual-motor model)

The next stage of the analysis was to determine the extent to which the errors of misclassification may be further reduced by combining those components, which improved classification accuracy or improved model fit within each category into a single regression model. For the two sway stance conditions where forwards stepwise and backwards elimination methods resulted in different regression models, the results of the forwards stepwise method of entry was used to select the components for entry into the combined perceptual-motor model. These components were considered to be consistent with our current understanding of the strategies used to maintain postural steadiness in double leg stance conditions. The 'combined' regression model resulted in the following equation regardless of which entry method was used.

$$\text{Logit(successful)} = 0.9899(\text{zdecage}) - 3.4832(\text{zso1}) + 1.6291(\text{zdc3}) - 1.2355(\text{ztimacc}) - 1.6153$$

Dynamic balance and the magnitude of the resultant sway motion during double leg stance eyes open were not included in the regression model. The signs of the coefficients of those variables included in the regression model were identical to those in the separate regression models. The goodness of fit of the model was 0.680, which indicated that a combination of talent characteristics from different categories improved the fit of the model to a greater extent than was possible using characteristics from any single category. It was also notable that the reduction in the log likelihood of block two was significant at the 1% level (block χ^2 = 17.562 [40.6%], p=0.001). In terms of classification accuracy, the model distinguished between successful and unsuccessful gymnasts with a high degree of accuracy with only three gymnasts being mis-classified (Table 6.12).

Table 6.12. Classification table for the logistic regression model including prognostic perceptual-motor characteristics

	Unsuccessful	successful	correct
Unsuccessful	20	1	95.2%
Successful	2	10	88.3%
		overall	90.9%

The value calculated for lambda indicated that errors in prediction were reduced by 75% in comparison with the 'constant only' model (λ =0.750, p= 0.001).

Summary

The results of the logistic regression analyses conducted within each category of perceptual-motor variables are summarised in Table 6.13.

Table 6.13. A summary of the results of the logistic regression analyses conducted within the perceptual-motor dimension of performance

	Lambda (λ)	d	P	block χ^2	p	R^2_Lmodel
decimal age	0.333	1.447	0.074	7.425 (17.2%)	0.006 **	0.172
sway DO	0.500	2.171	0.015 *	3.183 (7.4%)	0.074	0.245
sway DC	0.417	1.809	0.035 *	4.314 (10%)	0.038 **	0.271
sway SO	0.417	1.809	0.035 *	6.535 (15.1%)	0.011 *	0.271
timing accuracy	0.583	2.533	0.006 **	4.375 (10.1%)	0.037 *	0.273
dynamic balance	0.333	1.447	0.074	2.226 (5.1%)	0.136	0.223
av reaction time	0.333	1.447	0.074	-	-	0.172
combined model	0.750	3.257	0.001 **	17.562 (40.6%)	0.001**	0.680

* significant at the 5% level
** significant at the 1% level

Perceptual-motor characteristics improved classification accuracy above that achieved using decimal age as the sole independent variable with the exception of average reaction time and balance. In terms of both model fit and predictive efficiency, the perceptual-motor characteristics performed as well as the physical components reported in Chapter 5 (Table 5.25). In line with the results of the physical model, a combination of perceptual-motor characteristics best distinguished between successful and unsuccessful gymnasts. The summary model included timing accuracy and two components of postural sway (zso1 and zdc3).

6.4.3 LONGITUDINAL STABILITY

The longitudinal stability of the perceptual-motor characteristics was estimated using rank order autocorrelations with stability quantified according to the classification proposed by Malina (1996). There is a dearth of information concerning the stability of perceptual-motor characteristics which may be in part attributed to the difficulties associated with the measurement of these variables. This is particularly evident in the area of kinaesthesis for which no previous estimates of longitudinal stability have been reported.

Balance

As indicated by the results of the autocorrelations presented in Table 6.14 the longitudinal stability of functional balance performance was moderate to high.

Table 6.14. Longitudinal stability of the dynamic balance characteristic

	zbalance	
	time 2	time 3
time 1	0.470 *	0.480 *
time 2	----	0.690 **

There has been little agreement in the literature regarding the contribution of genetic factors to balance performance. However, the results of the present study provide tentative support for the path analytic study reported by Maes et al. (1996) in which heritability was reported to explain over 40% of the phenotypic variance in flamingo balance performance. The results of the present suggest that within the sample of young female gymnasts functional balance was relatively stable over the 12 month period of study. However, it remains to be established whether the observed stability reflects the contribution of genetic factors or is a function of specific gymnastic training.

Kinaesthetic characteristics

Timing accuracy was the only kinaesthetic characteristic which demonstrated adequate measurement reliability. This characteristic was also able to distinguish between successful

and unsuccessful gymnasts with a high level of classification accuracy (Table 6.11) However, as shown in Table 6.15 the longitudinal stability of timing accuracy was low to moderate and it is therefore concluded that further research will be required to determine the manner in which timing accuracy develops within the young female gymnast prior to its inclusion in the initial identification battery.

Table 6.15. Longitudinal stability of timing accuracy

	ztimacc	
	time 2	time 3
time 1	0.072	0.244
time 2	----	0.340

Average reaction time

As shown in Table 6.16 the longitudinal stability of the average reaction time characteristic was moderate. Although there have been no previous studies tracking reaction time, previous twin studies have reported the heritability of reaction time in response to a light stimulus to be in the range of 0.22-0.55 (Vandenberg, 1962; Sklad, 1973 op cit. Bouchard et al., 1997). More recently, estimates of transmissibility derived from large family studies employing path analytic techniques have reported transmissibility estimates in the order of 0.27 with the majority of the transmissibility associated with a genetic effect (Pérusse et al., 1988). These results support the findings of the present study (Table 6.16).

Table 6.16. Longitudinal stability of the average reaction time characteristic

	zavrt	
	time 2	time 3
time 1	0.332	0.422 *
time 2	----	0.285

6.4.4 PERCEPTUAL-MOTOR TALENT CHARACTERISTICS - GYMNASTS AND CONTROLS

In the following section, the extent to which perceptual-motor characteristics are able to distinguish between groups of gymnasts and controls will be examined. It should be remembered that the differences observed between gymnasts and controls may be due in part to the systematic training completed by the gymnasts over a number of years. However, any characteristics which distinguish between gymnasts and controls with a high level of classification accuracy, and are stable over time, are likely to be useful in the initial identification of gymnastic talent. In the testing session with the age-matched controls the sensitivity of the force plate was incorrectly set and as a result the sway data were excluded from all statistical analyses.

Logistic regression analysis

Decimal age

As demonstrated in Section 5.4.3 the reduction in the log likelihood associated with the entry of standardised decimal age as an independent variable was negligible at 0.4% (block χ^2=0.223, p=0.629). However, for consistency the hierarchical approach was retained in which decimal age was 'forced' into the regression model in the first block. The perceptual-motor characteristics were entered in the second block using stepwise procedures to determine the reduction in the log likelihood associated with their entry. Multicollinearity was assessed using linear regression analyses as detailed in Section 3.2. The range of tolerance values (0.781-0.971) were above the critical threshold of 0.20 reported by Menard (1995) which indicated that the level of collinearity in the data was acceptable.

Balance

The negative regression coefficient associated with balance indicated that the probability of being classified as a gymnast was associated with superior balance ability. The 34.5% reduction in the log likelihood was significant at the 1% level (block χ^2= 20.543,

p=0.006). However, the improvement in model fit was only moderate as indicated by the R^2_L value (0.348).

$$\text{Logit(gymnast)} = -0.9634(\text{zdecage}) - 2.4497(\text{zbalance}) - 0.9336$$

In comparison to the model which contained only a constant term, the inclusion of standardised balance ability reduced classification errors (Table 6.17). However, this reduction did not attain statistical significance at the 5% level (λ = 0.267, p=0.106). As a result of the poor classification accuracy it may be concluded that this assessment of balance ability would not be useful as part of the initial identification battery.

Table 6.17. Classification table for the logistic regression model including dynamic balance

	controls	gymnasts	correct
Controls	7	8	46.7%
Gymnasts	3	30	90.9%
		overall	77.1%

Kinaesthesis

Timing accuracy, the only reliable kinaesthestic measurement, was able to distinguish between gymnasts and controls. The sign of the coefficient indicated that gymnasts were associated with superior performances in the timing accuracy task. In line with the results presented above for dynamic balance, the reduction in the log likelihood was significant at the 1% level (block χ^2=19.709 [33.1%], p=0.006) and the fit of the model was moderate (R^2_L=0.334).

$$\text{Logit(gymnasts)} = -0.5738(\text{zdecage}) - 2.0081(\text{ztimacc}) - 0.9580$$

Classification accuracy as indicated by Lambda and the associated d statistic was significant at the 1% level (λ = 0.533, p=0.006).

Table 6.18. Classification table for the logistic regression model including kinaesthesis characteristics

	controls	gymnasts	correct
Controls	9	6	60.0%
Gymnasts	1	32	97.0%
		overall	85.4%

Given the nature of this measure and the observation that a number of subjects were misclassified the timing task could not be considered appropriate for use within the initial identification battery. Moreover, it is unlikely that very young children (5-6 years of age) would have the cognitive maturity to complete the test successfully. However, little is known about the longitudinal development and temporal stability of children's perception of timing and therefore it is recommended that this characteristic is monitored throughout the gymnast's career using an appropriate longitudinal approach.

Average reaction time

The change in the log likelihood associated with standardised average reaction time did not attain statistical significance at the 20% level and therefore this characteristic was not included in the regression model.

Logistic regression analysis (perceptual-motor model)

To examine the combined effect of perceptual-motor characteristics, a further regression analysis was conducted which included the prognostic indicators from each category. However, as a result of poor reliability within this dimension only two characteristics, balance and timing accuracy, were included.

$$\text{Logit(gymnasts)} = -1.2037(\text{zdecage}) - 1.8890(\text{zbalance}) - 1.8424(\text{ztimacc}) + 1.1229$$

As observed within the category models, the regression coefficients indicated that the probability of being classified as a gymnast was increased for those children demonstrating superior balance and a high level of accuracy in the perception of timing task.

Table 6.19. Classification table for the logistic regression model including prognostic perceptual-motor characteristics

	controls	gymnasts	correct
Controls	10	5	66.7%
Gymnasts	1	32	97.0%
		overall	87.5%

As expected, the combination of the two characteristics improved both the fit of the model (R^2_L=0.484) and the accuracy with which the children were classified as gymnasts and controls (λ = 0.600, p=0.018). However, even with the good model fit one third of the control subjects were misclassified using this combined model (Table 6.19).

Summary

The results of the logistic regression analyses conducted within each category of perceptual-motor variables for the pooled sample of gymnasts and controls are summarised in Table 6.20.

Table 6.20. A summary of the results of the logistic regression analyses conducted within the perceptual-motor dimension of performance (gymnasts and controls)

	Lambda (λ)	d	p	block χ^2	p	R^2_L model
decimal age	0.000	0.000	0.500	0.233 (0.4%)	0.629	0.004
dynamic balance	0.267	1.246	0.106	20.543 (34.5%)	0.006 **	0.348
timing accuracy	0.533	2.491	0.006 **	19.709 (33.1%)	0.006 **	0.334
av reaction time	0.000	0.000	0.500	-	-	-
summary model	0.600	2.083	0.018 **	28.803 (48.3%)	0.006 **	0.484

As a result of the reduced test battery and poor reliability only three perceptual-motor characteristics were included in the analysis. The model including timing accuracy

produced a moderate fit to the observed data and was most accurate in terms of classification. In comparison, the balance model was similar in terms of model fit but failed to classify gymnasts and controls with the same level of accuracy with 53.3% of control subjects misclassified. Both model fit and classification accuracy were improved when the combination of prognostic characteristics were included in a single regression model. However, given the heterogeneity of the 'pooled' sample, the classification accuracy of the summary model was disappointing with one third of control subjects misclassified. It is speculated that the poor performance of characteristics within the perceptual-motor dimension was a function of the failure to derive reliable assessments of these characteristics rather than their inability to distinguish between gymnasts and controls.

6.5 DISCUSSION

In comparison to the physical talent characteristics reported Section 5.1, the reliability of the perceptual-motor characteristics was poor. The perceptual-motor variables included in the test-retest reliability study were associated with large biological variability and low measurement reliability. Of these variables only balance demonstrated adequate reliability according to the thresholds for measurement bias and variability established in Chapter 5. Therefore, a number of perceptual-motor characteristics were excluded from all subsequent statistical analyses on the basis of unacceptable reliability.

The results of the logistic regression analyses conducted within each category revealed that several perceptual-motor characteristics were effective in distinguishing between successful and unsuccessful gymnasts. The regression models which included timing accuracy and postural sway components representing gymnasts' ability to maintain postural steadiness in challenging stance conditions (DC and SO) improved the accuracy of classification and/or the fit of the models. The statistically significant reductions in the log likelihood (5% level) associated with the inclusion of these characteristics indicated that the contribution of these variables could not be exclusively attributed to differences in the decimal age profile between successful and unsuccessful gymnasts. In line with the results of the physical chapter, the inclusion of several prognostic indicators within a single regression model further improved both model fit and classification accuracy. Although

the 'combined' model which included timing accuracy, zdc3 and zso1 did not achieve the 'perfect fit' observed for the combined physical model it did result in a good model fit (R^2_L = 0.680) and a high level of classification accuracy (λ = 0.750, p=0.001).

The results of the logistic regression analyses for the 'gymnasts only' sample were similar for physical and perceptual-motor characteristics in terms of model fit and classification accuracy. When the analyses were performed on the 'pooled' sample both indices showed a marked improvement within the physical dimension which was attributed to the greater heterogeneity of the 'pooled' sample. In contrast, this improvement was not observed within the perceptual-motor dimension. However, it is speculated that this lack of improvement was due to the poor measurement reliability which restricted the number of independent variables rather than the limited ability of perceptual-motor characteristics to distinguish between gymnasts and controls. Moreover, the omission of the sway data for the control subjects was unfortunate given the level of accuracy with which sway components were able to distinguish between successful and unsuccessful gymnasts (Table 6.13). It is recommended that future research is carried out to establish the prognostic value of sway components by examining the differences between gymnasts and controls. If differences are observed between gymnasts and controls, longitudinal research will be necessary to determine whether these differences are a function of innate ability or the result of long term adaptations to gymnastic training.

Few studies have investigated the control of postural sway in young athletic females. To provide a comprehensive overview of postural steadiness in the present sample of young female gymnasts parameters were determined for a series of progressively challenging stance conditions in both time and frequency domains. Four principal components were derived within each stance condition (DO, DC and SO) which accounted for a large proportion of the variance in the data (82.7%-88.9%). It was interesting to observe that all components explained a similar amount of variance. The components comprised variables from either the time or the frequency domain with the exception of components zdo1 and zso1 which included a combination of time and frequency-based variables. Within each stance condition at least one component combined information relating to the

movement of the centre of pressure in both anterior-posterior (a_y) and medial-lateral (a_x) directions.

The results of the logistic regression analyses indicated that in general, success in gymnastics was associated with greater postural steadiness and lower frequency oscillations. However, it was interesting to observe that within the DO stance successful gymnasts maintained steadiness in the medial-lateral direction using relatively high frequency oscillations compared to their less successful peers. It was speculated that this may represent the use of an alternative strategy by the successful gymnasts. This idea was supported by the results of the DC stance in which the successful gymnasts were distinguished from less successful gymnasts on the basis of the frequency distribution of their sway in the medial-lateral (a_x) direction. Within the DC stance successful gymnasts produced smaller maximum powers in the a_x direction but, as was observed in the DO stance, the cumulative power of the signal was shifted towards the high frequency end of the spectrum in comparison with gymnasts of a lower standard. The observation that relatively high frequency oscillations in the medial-lateral direction were associated with gymnastic success in both double leg stances supports the contention that successful gymnasts adopt a strategy involving higher frequency oscillations to control the movement of the mass centre and thereby achieve postural steadiness in this direction.

As a group, the successful gymnasts were older than the less successful gymnasts and therefore, the observed results may be considered to reflect the longitudinal development of balance ability within the growing child. However, several studies report that a mature level of postural stability is attained in the lower extremity musculature in response to platform perturbations between 7-10 years of age (Woollacott et al., 1987). Postural steadiness within relatively stable double leg stances would be expected to mature in advance of postural stability responses and therefore the chronological age difference between groups is not anticipated to explain the observed results. The reasons why the successful gymnasts adopted such a strategy are unclear but are suggested to be a function of their enhanced ability to detect sway and to correct for medial-lateral movements of the mass centre away from the base of support. It is speculated that this increased acuity may be a function of training and may develop specifically in response to training on the beam. Gymnasts predominantly work the beam 'crossways' and therefore it may be expected that

such training would result in the development of strategies specific to the medial-lateral direction. Further research is needed to confirm the association between gymnastic success and the presence of high frequency oscillations in the medial-lateral direction during double leg stances and to examine the implications of this strategy in terms of postural steadiness.

Previous studies have examined changes in postural steadiness as subjects move between stance conditions using the Romberg quotient which expresses the ratio between postural steadiness in DO and DC stance conditions (Era & Heikkenen, 1985; Goldie et al., 1994; Frank et al., 1989; Hufschmidt et al., 1980; Lucy & Hayes, 1985; Baloh et al., 1994). The Romberg quotient was calculated for resultant signal energy, sway path and the standard deviation in both medial-lateral (a_x) and anterior-posterior (a_y) directions. These quotients were subsequently standardised and entered in the second block of separate hierarchical regression models as described previously. The changes in the log likelihood associated with the entry of the Romberg quotients for resultant signal energy, sway path and standard deviation in the anterior-posterior (a_y) direction did not attain statistical significance at the 20% level and these parameters were not included in the regression models. The Romberg quotient for standard deviation in the medial-lateral (a_x) direction was included in the regression equation and was associated with a positive coefficient. This indicated that successful gymnasts, upon closing their eyes, experienced a greater increase in the amplitude of sway in the medial-lateral direction compared with their less successful peers. This suggests that while the successful gymnast may be adopting a particular strategy in this direction, it was not effective in enhancing steadiness in the absence of vision. Changes in postural steadiness were also examined as gymnasts moved between double and single leg stance conditions using the ratio of SO:DO. The ratios of the same four independent variables described above were entered into separate logistic regression models. The ratio derived from sway path was the only independent variable included in the regression model. The negative coefficient associated with this variable indicated that the successful gymnasts increased their sway to a lesser extent when moving to a single leg stance compared with the less successful gymnasts. While the ratio data assists our understanding of the manner in which gymnasts adapt to different stance conditions, inclusion of these ratios within the regression models did not enhance classification accuracy.

Previous studies have evaluated static balance in terms of the length of time a given stance condition can be maintained (Sol, 1987; Hahn et al., 1999). According to these studies static balance was of limited value in differentiating between gymnasts and controls (Hahn et al., 1999) and in the prediction of future gymnastic performance (Sol, 1987). Results of the present investigation suggest that static balance is important but that differences between individuals may only be detected when measured with an appropriate level of sophistication. However, the need for a sophisticated measurement system precludes the use of static balance in the initial identification of talent within a mass screening situation.

A comprehensive longitudinal investigation of postural steadiness in gymnasts and controls will be required to determine whether differences exist between the two groups. Furthermore where differences exist it will be necessary to establish whether they are due to innate ability or have developed as a result of gymnastic specific training. A clear understanding of the longitudinal development and maturation of the postural control system within the young female gymnast will be particularly important given its stage-like development (Woolacott & Sviestrup, 1992). The apparent regression of the young child's ability to respond to postural perturbations, associated with the development of inter-sensory integration, which occurs between 4-6 years of age (Shumway-Cook & Woollacott, 1985) coincides with the timing of the initial identification of gymnastic talent. Therefore, it may be concluded that the use of postural steadiness as an indicator of gymnastic aptitude is inappropriate. The stage-like development of postural stability also has important implications for the structure and organisation of training within the sensitive period between 4-6 years of age. Over-emphasis upon any one particular aspect of balance ability may be detrimental at this time. Therefore, it is recommended that during this period gymnasts are provided with a wide range of movement and sensory experiences to facilitate inter-sensory integration and enhance the development of postural control.

The modified version of the Nelson balance test (Johnson & Nelson, 1986 op cit. Kirby, 1991) provided a field based assessment of static and dynamic balance. The standardised score was included in the regression models for both 'gymnasts only' and 'pooled' samples and the negative regression coefficients indicated that gymnastic success was associated with superior balance ability. However, the classification accuracy was poor within the

two samples which was disappointing given the inclusion of balance ability in a number of identification batteries (Vankov, 1978; Salmela et al., 1979; Peltenburg et al., 1982; Rozin, 1986; Régnier & Salmela, 1987; Sol, 1987; Risack et al., 1988; Poelvoorde & Levarlet-Joye, 1990). Moreover, the inability of the functional balance assessment to distinguish between gymnasts and controls was surprising considering the heterogeneous nature of the pooled sample. It is hypothesised that the modified Nelson balance test was not sufficiently sensitive to detect group differences. Support for this suggestion may be derived from Peltenburg et al. (1982) who reported that gymnasts selected as talented had better dynamic balance than those who were initially selected as talented and subsequently discharged. However, differences between the groups were only apparent when the assessment of dynamic balance was performed in the absence of vision. It may be concluded the assessment of dynamic balance used it the present study was not difficult enough to detect any differences between groups.

The present study examined the three main components of kinaesthesis; the sense of joint position and movement, the perception of force or effort associated with muscular contractions and the perceived timing of muscular actions (McCloskey, 1987; Gandevia et al., 1992; Enoka, 1994). The gymnast's sensation of joint position and movement was assessed about both postural and extrapersonal frames of reference using the matching and pointing tasks respectively. It was hypothesised that the sensation of joint position and movement would be important in young female gymnasts given the nature of skill development and in particular the emphasis placed upon 'shaping'. The three conditions incorporated within the matching task were designed to provide an insight into the extent to which gymnasts were able to use information from cross and intra-modal sources. It was anticipated the results of these assessments would be useful in determining the most effective coaching strategies to use with young female gymnasts. Moreover, it was hoped that these assessments may also identify gymnasts deficient in kinaesthetic awareness so that appropriate remedial programmes may be employed. Such programmes have been shown to be effective within the academic environment (Laszlo & Bairstow, 1985). It was therefore disappointing that as a result of poor measurement reliability (Table 6.2), the matching and pointing tests could not be included in the logistic regression analyses.

The ability to perceive and exert appropriate levels of muscular force is important in gymnastics. For example, during a take-off the gymnast has a limited amount of time to produce the appropriate amounts of flight and rotation to perform the desired skill. In the present study the perception of force was assessed according to the gymnast's ability to produce sufficient muscular effort to complete exactly 50% of their maximal standing broad jump. Despite efforts to ensure that gymnasts understood the demands of the task, reliability was extremely poor in terms of both bias and measurement variability. The perceived timing of muscular actions assessed using a single segment simulation model was the only kinaesthetic assessment which demonstrated adequate reliability. The results of the logistic regression analysis for the 'gymnasts only' sample highlighted that future success in gymnastics was associated with timing accuracy. A negative coefficient indicated that successful gymnasts had more accurate perceptions of timing. The inclusion of timing accuracy as an independent variable improved both model fit and classification accuracy. A similar pattern of results was observed for the 'pooled' sample. These results indicated that timing accuracy is a potentially important talent characteristic which can be reliably measured using a simple field test. However, the longitudinal stability of this characteristic was low to moderate which indicated that while this assessment may have utility in the identification of talent, further research will be required to determine the longitudinal stability and the manner in which timing accuracy develops within the young female gymnast.

Reaction time was assessed within a series of relatively complex whole body movements. This was deemed appropriate based on the findings of Thomas & Mitchell (1996) who failed to find a significant difference between elite gymnasts and untrained controls in terms of simple reaction time in response to a visual stimulus. While the assessment of reaction time employed in the present investigation was assumed to be reliable and demonstrated moderate longitudinal stability it failed to distinguish between groups in the 'pooled' and 'gymnasts only' samples. Therefore, the assessment of simple reaction time employed in the present investigation will not be considered for inclusion in the initial identification battery.

6.6 *SUMMARY*

Within the perceptual-motor dimension the major concern highlighted in the present study was the lack of adequate measurement reliability. Therefore, several characteristics, which were perceived to be likely indicators of future gymnastic performance, could not be included within the logistic regression analyses. Those perceptual-motor characteristics which demonstrated adequate reliability were effective in distinguishing between groups within the 'gymnasts only' and 'pooled' samples. In comparison with the physical talent characteristics, variables from the perceptual-motor dimension produced similar results in terms of model fit and classification within the 'gymnasts only' sample. However, for the pooled sample the marked improvement in fit and classification accuracy reported in the physical dimension was not observed for the perceptual-motor characteristics. This would suggest that the current assessments are of limited utility in the initial identification of gymnastic talent. It is therefore recommended that the current assessments of perceptual-motor characteristics are not included within the initial test battery.

It is recommended that, of the reliable perceptual-motor characteristics, postural steadiness and timing accuracy are incorporated within the longitudinal monitoring of young female gymnasts. It will be particularly important to monitor the development of postural steadiness on a regular basis given the potential implications the stage-like development of this characteristic may have for the organisation of gymnastic training. Moreover it will be necessary to investigate further the mechanisms gymnasts employ to control postural steadiness in the medial-lateral direction.

MONITORING DEVELOPMENT (PROFILING)

postural sway:	DO, DC and SO stance conditions
kinaesthesis:	perception of timing

Finally, it is recommended that future research is directed towards refining the measurement procedure so that the reliability of perceptual-motor characteristics may be enhanced. It is anticipated that this will be a difficult task since the greater experimental

control required to enhance internal validity is likely to compromise the external validity of the measurements and the extent to which they may be employed practically within a mass screening situation. Once a reliable measurement battery has been produced it will be necessary to conduct a comprehensive longitudinal investigation to monitor the development of perceptual-motor characteristics within the young female gymnast. Only through such an approach will the predictive validity of these characteristics be determined.

CHAPTER 7

PSYCHOLOGICAL CHARACTERISTICS

7.1 INTRODUCTION

Previous chapters have examined the relationship between social-demographic, physical and perceptual-motor talent characteristics and future gymnastic performance. The aim of these chapters was to determine which, if any, of the selected characteristics may be considered prognostic indicators of talent in young female gymnasts. The intention of the present chapter is to extend this analysis to include characteristics from the psychological dimension. Psychological talent characteristics have rarely been included in test batteries designed to identify and develop gymnastic talent. 'Psychological' assessments were occasionally included in Eastern European systems (Chernechenko, 1982; Rozin, 1986; Fadeev, 1994). However these assessments generally examined the gymnast's behavioural qualities and bear little resemblance to the constructs which characterise the current social-cognitive perspective adopted within sports psychology.

Goal perspective theory (Nicholls, 1984, 1989) is a well established developmental theory of achievement motivation which has been extensively tested within the domain of youth sport. Therefore, the theory was considered to be an appropriate framework through which to examine the nature of talent identification and development within young female gymnasts. The present chapter will examine the relationship between a number of psychological constructs inherent within goal perspective theory and future gymnastic performance. More specifically, the extent to which the selected psychological constructs are able to distinguish between successful and unsuccessful gymnasts will be determined.

In the absence of a sound theoretical framework upon which to base the selection of talent characteristics, the previous chapters were largely exploratory in nature. It was therefore considered appropriate that within the social-demographic, physical and perceptual-motor dimensions only main effect terms would be selected for inclusion in the regression models. In contrast, the theoretical framework underlying goal perspective theory is well established within the domain of youth sport (Nicholls, 1984, 1989; Duda, 1992, 1993a,b;

Roberts, 1992). It was therefore considered appropriate to examine both main and interaction effects consistent with the theoretical tenets of goal perspective theory.

7.2 REVIEW OF LITERATURE

Goal Perspective Theory

Within the fields of educational and sports psychology a number of social-cognitive theories have been advanced to interpret the nature of achievement motivation (Harter, 1978; Nicholls, 1989; Eccles & Harold, 1991). One such approach, Goal Perspective Theory, has focused upon the development of achievement goals and the behavioural consequences associated with adopting a particular goal orientation or state of involvement (Nicholls, 1984, 1989; Dweck, 1986; Elliot & Dweck, 1988; Ames, 1984; Ames & Archer, 1988). This theoretical framework was originally developed within education and has more recently been applied within the context of sport and physical education (Duda, 1989a, 1992; Fox, Goudas, Biddle, Duda & Armstrong, 1994; Duda, Fox, Biddle & Armstrong, 1992). Over the past decade a large number of studies have examined aspects of the theoretical framework proposed by John Nicholls (1984, 1989) and other Goal Perspective Theorists and provided evidence in support of the main tenets of the theory within the domain of youth sport (Duda, 1992, 1993a,b; Roberts, 1992; Duda & Whitehead, 1998). More recently, aspects of Goal Perspective Theory associated with the conceptualisation and measurement of achievement goals have attracted critical attention (Hardy, 1997, 1998; Harwood, Hardy & Swain, in press). However, the critical appraisal of research is integral to the advancement of scientific theory and while the impact of such criticisms continues to be debated Goal Perspective Theory remains one of the most popular frameworks for the study of achievement motivation in sport.

Proponents of goal perspective theory consider the individual to be an intentional, goal-directed organism who acts in a rational manner to realise his/her achievement goals (Nicholls, 1984). Nicholls (1984, 1989) contends that the major goal in achievement situations is to demonstrate high ability and/or avoid the demonstration of low ability. However, individuals are hypothesised to construe their ability in different ways and understanding the subjective meaning of ability held by an individual is considered essential

to the understanding of achievement behaviour (Roberts, Treasure & Balague 1998). According to Nicholls (1984, 1989) two goal states, task and ego involvement, are manifest within achievement situations with the adoption of a particular goal state in mature individuals dependent upon whether the individual holds an undifferentiated or differentiated conception of ability (Nicholls, 1984; Nicholls & Miller, 1984; Treasure & Roberts, 1998).

An individual is reported to be task involved (TI) when he/she holds an undifferentiated conception of ability and as such views effort as synonymous with ability. TI individuals evaluate their ability according to self-referenced criteria and perceive success to be a function of improvements in personal performance and/or the acquisition of mastery in a given skill or task. The individual who adopts a state of ego involvement (EI) holds a differentiated conception of ability in which the constructs of effort and ability are distinct from each other and ability is perceived to reflect capacity. The EI individual compares his/her ability with a normative referent and defines success in terms of the demonstration of superior performances over others. In comparison with an individual adopting a state of TI, the EI individual employs relatively sophisticated reasoning to evaluate competence (Roberts, 1984; Duda, 1993b). Specifically, the EI individual evaluates the outcome of a task in relation to the amount of effort exerted and the ability of both players (Duda, 1993b). High ability can be construed when an individual produces a superior performance with the exertion of equivalent and/or reduced effort or alternatively achieves a similar performance with less effort (Jagacinski & Nicholls, 1984; Nicholls, 1984).

Goal perspective theory proposes that the goal state held by an individual is related to the way that individual will behave, act and feel in a particular achievement context. A crucial aspect of the theory concerns the mediating role of the individual's perceptions of his/her ability (Roberts, 1984). A state of TI is associated with adaptive patterns of motivational behaviour irrespective of perceived ability, where adaptive motivational behaviours include the selection of optimally challenging tasks, the application of effort and task persistence (Nicholls, 1984, 1989; Fox et al., 1994; Duda, 1993a,b; Duda, Chi, Newton, Walling & Catley, 1995). In contrast, the relationship between EI and behaviour is moderated by the construct of perceived ability. The EI individual who perceives his/her ability to be high will demonstrate adaptive patterns of behaviour similar to the TI individual. However, the

EI individual who is unsure of his/her ability is predicted to demonstrate maladaptive behaviours which include the avoidance of moderately challenging tasks, low persistence and a lack of applied effort (Duda, 1993a,b). The selection of tasks which are either very easy or difficult is regarded to be rational given that the goal is to avoid the demonstration of low ability. By selecting very easy tasks in which the individual is sure of success the demonstration of low ability is avoided. Moreover, failure at very difficult tasks at which few individuals would be expected to succeed will not inevitably indicate low ability. The EI individual with low perceived ability would also be unlikely to apply large amounts of effort given that failure in this situation would reveal an obvious lack of ability (Roberts, 1984).

According to Nicholls (1989) the states of task and ego involvement, like the associated dispositional goal orientations, are orthogonal and it is therefore possible for a mature individual to experience different levels and/or combinations of these states. The concept of orthogonality is one of the major conceptual differences between achievement goal theorists (Roberts, 1992). For example, Dweck rejected the concept of orthogonality and rather considered 'learning' and 'performance' goals to lie at opposite poles of a single continuum (Dweck, 1986; Dweck & Leggett, 1988). With reference to the issue of orthogonality, Harwood et al. (in press) questioned Nicholls' conceptualisation of goal states and specifically the conditional dependence of these states upon the differentiated and undifferentiated conceptions of ability. The authors suggested that the attainment of a mature conception of ability was incompatible with the concept of orthogonal goal states rejecting Nicholls' (1989) contention that an individual may employ either conception in accordance with the demands of the situation. To illustrate their point Harwood et al. (in press) cited the example of a mature individual high in task and ego orientation and questioned which conception of ability such an individual would be theorised to hold.

According to the theoretical framework proposed by Nicholls (1989) the goal state employed by an individual at any particular time is a function of three factors (Duda, 1987, 1993a,b; Nicholls, 1989); the cognitive developmental status of the individual (Nicholls & Miller, 1984), the proneness or disposition of the individual to adopt a particular goal state and the prevailing characteristics of the situation (Jagacinski & Nicholls, 1984; Nicholls & Miller, 1984; Ames, 1992). These factors are of considerable importance in the

understanding and interpretation of achievement behaviour within sport and will be discussed in the following sections.

Developmental differences

Nicholls (1989) suggested that a mature conception of ability reflects three inherent assumptions concerning the interdependent constructs of ability, task difficulty and effort. Firstly, it was assumed that ability is defined by skill which is distinct from luck or chance. Secondly, it was assumed that the difficulty of a task is evaluated through normative comparisons, with the most difficult tasks being those which few individuals are able to complete successfully. The third and final assumption stated that ability and effort are differentiated and that a mature conception of ability embodies the notion of ability as capacity (Nicholls, 1989; Fry & Duda, 1997). One of the main strengths of Nicholls' Goal Perspective theory is that it is developmental in nature (Duda, 1987) and embodies a recognition that the constructs of effort, ability and task difficulty have different meanings to children depending upon their level of cognitive maturity (Nicholls & Miller, 1984; Duda, 1987). As a result of these developmental differences children construe their competence in a manner that is consistent with their level of cognitive maturity and exhibit patterns of behaviour appropriate to their level of reasoning. From observations reported in several empirical studies (Nicholls, 1978; Nicholls & Miller, 1983; Nicholls & Miller, 1984) Nicholls (1989) proposed a developmental sequence through which the constructs of effort, ability and task difficulty become progressively differentiated until a mature conception of ability is achieved at approximately 11-12 years of age. Moreover, this developmental sequence has been reported to hold irrespective of whether children's reasoning concerns their personal performance or the performance of others (Nicholls & Miller, 1984; Nicholls, 1989).

Differentiation of ability and task difficulty

The differentiation of ability and task difficulty was proposed to occur over three levels (Nicholls, 1980; Nicholls & Miller, 1983). The very youngest children were purported to hold an 'ego-centric' conception whereby the difficulty of the task was determined according to children's perceptions of whether they personally were to able to complete

the task irrespective of the performance of others. By approximately five to six years of age children adopted an 'objective' conception and had begun to understand that more difficult tasks required more ability (Duda, 1987). However, it was not until the third level when children were approximately seven years of age that ability and task difficulty became fully differentiated. This final level was characterised by the adoption of a 'normative' conception in which high ability was defined as the successful performance of a task which few other children were able to complete.

Differentiation of effort and ability

To examine the developmental progressions leading to the differentiation of effort and ability Nicholls (1978) showed children of various ages film of two children completing a 'maths' problem. One of the children in the film worked 'diligently' while the other was clearly 'lazy' working on the task only intermittently, however, both were awarded the same performance score. Nicholls (1978) applied the method of critical exploration developed by Piaget to objectively assess the extent to which children understood that the 'lazy' child scored the same as the 'diligent' child as a result of greater ability. Moreover, the extent to which they understood that if both children exerted equal amounts of effort, the 'lazy' child would be expected to score higher. This reasoning was assumed to reflect the child's ability to differentiate between the concepts of effort and ability. Four developmental levels were observed which were assumed to reflect successive stages of cognitive development (Nicholls, 1978, 1980; Nicholls & Miller, 1983, 1984). In the youngest children, who were approximately five years of age, effort and ability were considered to be synonymous and reflected an undifferentiated conception which was maintained irrespective of evidence to the contrary. Levels two and three were intermediate stages in which the concepts of effort and ability were partially but not systematically differentiated. It was not until level four, when children were approximately 11-12 years of age, that a mature differentiated conception of ability was observed in which ability was viewed as a capacity which acts to constrain the impact of effort upon performance. In a recent study, Fry & Duda (1997) observed a similar developmental progression for the differentiation of effort and ability for both academic and sporting tasks. However, an additional 'zero' level of ability was reported to precede the four level classification proposed by Nicholls (1978).

A clear understanding of the developmental stages through which children progress towards a differentiated conception of ability is necessary in order to understand the cognitions and behaviour demonstrated by children in achievement situations. Specifically, children interpret the consequences of their actions in a manner commensurate with their level of reasoning. For example, in a young child who holds an undifferentiated conception of ability the completion of a task through the application of considerable effort is associated with learning. In contrast, to an older child demonstrating a mature level of differentiation, the application of high levels of effort may be interpreted to indicate low ability. It has been speculated that the attainment of a mature conception of ability and the view that ability is capacity is associated with the high rates of attrition observed in youth sport at approximately 12 years of age (Roberts, 1984).

Several studies have reported large inter-individual differences in the age of children at each level of differentiation (Nicholls, 1989; Fry & Duda, 1997). The study by Fry & Duda (1997) indicated that while the majority of children applied the same level of reasoning across dimensions, where differences were observed, children tended to adopt a more mature conception of ability in the physical domain. This observation was suggested to reflect the nature of competitive sport and in particular the visual processes of performance and evaluation which characterise sporting events. Furthermore, Fry & Duda (1997) speculated that children who participated in competitive sport from a young age may experience an accelerated progression with respect to the differentiation of effort and ability and may demonstrate more mature levels of reasoning when compared with non-athletes.

Dispositional proneness

A large proportion of the early research in support of goal perspective theory focused upon the individual's dominant dispositional orientation. Associations were consistently observed between the dominant goal orientation and motivational correlates of behaviour within achievement situations (Nicholls, 1984, 1989; Duda, 1992, 1993a; Roberts et al., 1998). Sports specific inventories such as the Task and Ego Orientation in Sport Questionnaire (TEOSQ) (Duda, 1989, 1992) and the Perceptions of Success

Questionnaire (POSQ) (Roberts & Balague, 1991; Roberts et al., 1998) were developed to measure dispositional goal orientation within the domain of sport. Studies using these inventories have provided consistent support for the hypothesised relationships between achievement goal orientations and motivational correlates of behaviour within sport and exercise domains. For example, a positive association has been observed between task orientation and various indices of intrinsic motivation including enjoyment and inherent interest in sporting activities (Duda et al., 1995; Duda et al., 1992; Duda & Nicholls, 1992). A task orientation has also been associated with the belief that success in sport occurs as a result of effort, hard work and collaboration (Duda et al., 1992; Duda & Nicholls, 1992). In contrast, an ego orientation has consistently been associated with maladaptive achievement behaviours such as work avoidance and a reduction in intrinsic interest (Duda et al., 1995). Moreover a positive relationship has been repeatedly observed between ego orientation and the belief that success in sport occurs as a result of possessing a superior ability (Duda, 1989b op cit. Fox et al., 1994; Duda & Nicholls, 1992; Duda et al., 1992; Lochbaum & Roberts, 1993; Boyd & Callaghan, 1994).

As a result of the consistency of the relationship between task orientation and adaptive achievement behaviours, the promotion a task orientation has been advocated within sport and physical education (Fox et al., 1994). Moreover, in light of the reported associations between an ego goal orientation and maladaptive achievement strivings, proponents of goal perspective theory have recommended that ego goals are de-emphasised (Fox et al., 1994). However, as highlighted by Fox et al. (1994) and subsequently by Hardy (1997) these recommendations have neglected several assumptions inherent within goal perspective theory. Firstly, they have failed to consider the role of perceived ability which mediates the relationship between a state of ego involvement and achievement behaviour (Nicholls, 1984) such that an ego orientation will only be detrimental in those individuals who have low perceptions of their ability (Hardy, 1997, 1998; Berlant & Weiss, 1997; Harwood et al., in press). Secondly, as previously discussed, the states of task and ego involvement are assumed to be orthogonal which implies that an individual may experience combinations of task and ego involvement (Nicholls, 1989; Hardy, 1997; Duda, 1993a,b). The hypothesised orthogonality of task and ego orientations has been confirmed in the literature with most studies reporting low correlations between task and ego sub-scales (Duda & Nicholls, 1992; Duda et al., 1992; Duda, 1993a,b; Goudas, Biddle & Fox,

1994; Chi & Duda, 1995). However, until recently, most empirical investigations have focused upon the dominant goal orientation and have neglected to examine the impact of different combinations of task and ego goal states upon indices of motivation and behaviour.

Goal profiles

Goal profiles were introduced to sport and exercise psychology research by Fox et al. (1994) and provided a technique through which the motivational consequences of various combinations of task and ego orientation could be examined. A number of studies have subsequently adopted the goal profile approach to examine the relationships between achievement goals and indices of motivation within the context of sport (Stephens, 1998) and physical activity (Goudas et al., 1994). In their original study Fox et al. (1994) created goal profiles for a large sample of British children using mean splits of the sub-scale scores for task and ego orientation. Multivariate statistical analyses (MANOVA) indicated that the level of task orientation was the critical determinant of enjoyment and motivation in sport. However, it was interesting to observe that ego involvement did not appear to have a detrimental effect upon motivation when experienced in the presence of a high task orientation. Moreover, the high task-high ego (HiT-HiE) group reported higher levels of sport enjoyment and demonstrated the highest motivation. These results provided support for recent contentions that an ego goal orientation is not necessarily detrimental to performance (Hardy, 1997, 1998).

In the 1996 Coleman Roberts Griffiths address one of the 'myths' discussed by Hardy was that ego orientations have a detrimental effect on variables relating to sporting performance. Hardy highlighted that in theory a high ego orientation may only be associated with negative consequences for sporting performance when athletes perceive their ability to be low. In addition, Hardy contented that an ego orientation will not necessarily have a negative effect in those athletes who adopt multiple goals from which they may derive information concerning their competence. The task component of the high task-high ego (HiT-HiE) profile has been suggested to provide the athlete with a facilitatory mechanism through which their competence may be preserved in the event that

the normatively referenced competence becomes threatened (Duda, 1997). A similar interpretation of the high task-high ego state goal profile was reported in a study of age-group swimmers (Swain & Harwood, 1996) with a state of high task involvement interpreted to provide secondary source of satisfaction.

Situational factors

In addition to the influence of dispositional goal orientation, situational factors were proposed to have a major role in determining the goal state adopted by an individual (Nicholls, 1989; Duda, 1992, 1993a,b, 1996). Ames (1984, 1992) referred to the situational goal structure as the motivational climate, with situations classified as mastery or performance orientated depending upon the extent to which cues within the environment evoked a state of task or ego involvement (Ames, 1992). It has been suggested that children's experiences and critically their perceptions of environmental cues have an impact upon the adoption of a goal state and consequently upon achievement behaviour (Ames, 1992; Ntoumanis & Biddle, 1998). Various aspects of the motivational climate relating to the organisation of the situation and the behaviour of significant others may encourage the adoption of a state of goal involvement. Within a sporting situation such aspects may include the establishment of goals, the organisation of children into training groups, the manner in which performances are evaluated and the prevailing reward structure (Ames & Archer, 1988; Duda, 1997; Ntoumanis & Biddle, 1998). For example, within a task involved motivational climate each individual is regarded as a valued team member with emphasis placed upon the merits of teamwork and cooperation. Improvements in personal performance and skill development are highly valued with a reward structure stressing the merits of hard work and effort (Seifriz, Duda & Chi, 1992; Duda, 1993a,b; Newton & Duda, 1999). In contrast, an ego involved motivational climate may be evoked within situations which emphasise inter-personal competition and rivalry between members within a team or squad. Individuals tend to be grouped on the basis of their ability with attention focused primarily upon the talented or gifted members of the group. Moreover, an ego involved motivational climate has been associated with a strong emphasis upon the outcomes of performance and the perception that errors are likely to engender punitive measures.

In line with the major tenets of goal perspective theory perceptions of the motivational climate were hypothesised to evoke a state of goal involvement and thereby influence the thoughts, feelings and behaviour of the individual. Perceptions of a task involved climate have been consistently associated with motivationally adaptive responses while an ego involved climate has been traditionally associated with maladaptive achievement behaviour (Ames, 1992). For example, in classroom-based research, Ames & Archer (1988) reported that children who perceived the situation to be task involving demonstrated the most effective learning strategies and reported a greater enjoyment of the academic experience. Perceptions of a task involved, or mastery climate, were also positively associated with the belief that success in the classroom stemmed from effort. It was particularly noteworthy the subjects within Ames & Archer's (1988) study included pupils classified as academically gifted. The relationship between perceived motivational climate and achievement behaviour, cognitions and affect has been confirmed within the context of sport and physical education (Seifriz et al., 1992; Walling et al., 1993; Theeboom, De Knopp & Weiss., 1995; Treasure & Roberts, 1994 op cit. Newton & Duda, 1999). In an early study, Seifriz et al. (1992) developed the Perceived Motivational Climate in Sport Questionnaire (PMCSQ) and applied the inventory to examine the relationship between perceived motivational climate and indices of motivation within high school basketball players. In line with theoretical expectations, perceptions of a task orientated climate were positively related to enjoyment in basketball and the belief that success stems from the application of effort. In contrast, those athletes who perceived the situation to be ego orientated reported lower levels of enjoyment and held the belief that success occurred as a result of superior ability.

The results of empirical studies conducted across performance domains have consistently provided evidence in support of the hypothesised relationships. Perceptions of a task involved motivational climate have been associated with greater enjoyment (Seifriz et al., 1992) and satisfaction (Walling, Duda & Chi, 1993) while ego involvement has been associated with worry and anxiety concerning the adequacy of performance and negatively associated with satisfaction (Walling et al., 1993). Moreover, with respect to cognitions, perceptions of a task involved motivational climate have been associated with the belief effort leads to success (Treasure & Roberts, 1998) while perceptions of an ego involved climate have been associated with belief that success results from possessing a high level of

natural ability or talent (Seifriz et al., 1992; Treasure & Roberts, 1998). A number of studies have employed hierarchical regression procedures to evaluate the relative influence of dispositional and situational factors (Seifriz et al., 1992; Newton & Duda, 1999). In line with the findings of Duda & Nicholls (1992) these studies have consistently confirmed that affective responses were largely influenced by perceived motivational climate whereas beliefs were more closely predicted by dispositional goal orientation (Seifriz et al., 1992; Newton & Duda, 1999).

As a result of the consistent relationship observed between situational factors and subsequent achievement behaviour, the majority of achievement goal theorists have recommended that coaches provide environmental cues which are likely to evoke a task orientation and de-emphasise or suppress ego goals (Duda, 1992; Treasure, 1997; Treasure & Roberts, 1998). However, one of the major limitations of early research concerns the exclusive focus upon the analysis of main effects and the failure to consider the assumption that the dispositional goal orientation of the individual and situational factors interact to influence achievement behaviour (Nicholls, 1989; Treasure & Roberts, 1998). Within an interactionist approach, the dispositional goal orientation is associated with a probability that a particular goal state will be evoked, however, situational factors have the potential to influence this probability (Dweck & Leggett, 1988). Therefore, the adoption of a particular goal state is considered to depend upon the relative strength of the dispositional goal orientation and the strength of environmental cues to displace or complement this orientation (Treasure & Roberts, 1995).

Interaction effects

Several recent investigations have adopted an interactionist approach to examine the manner in which dispositional and situational variables interact to influence goal states and various indices of achievement behaviour (Swain & Harwood, 1996; Harwood & Swain, 1998; Treasure & Roberts, 1998; Newton & Duda, 1999). The recent prevalence of studies adopting an interactionist approach may be attributed to the introduction of moderated hierarchical regression analysis to the field of achievement goals by Swain & Harwood (1996). In their innovative study, Swain & Harwood (1996) examined the

separate and interaction effects of dispositional goal orientations and situational variables upon pre-competition goal states in age group swimmers. The results indicated that both dispositional and situational variables were important in predicting pre-competition goal states. Situational variables were shown to be the major predictors of ego involvement while dispositional task orientation best predicted the state of task involvement. The use of graphical representation techniques clearly illustrated the nature of the interaction between situational variables and dispositional goal orientations upon task involvement in swimmers. It was particularly interesting to observe the moderating effect of those situational variables relating to the individual's perceptions of the state goal preference of significant others. Specifically, when the preferred state goal of significant others was perceived to be task involved, the trait goal appeared to have only a minimal effect upon the state of task involvement. In other words the situational variable 'complemented' a high task orientation and 'moderated' a low task orientation. In contrast, when the perception of the state goal preference of significant others was ego involved, the task orientation of the individual had an obvious impact upon the state goal. Specifically, a weak task orientation resulted in a low state of task involvement whereas a high task orientation increased the level of task involvement by a large amount. In a subsequent study of junior tennis players Harwood & Swain (1998) confirmed the powerful influence of the perceived state goal preference of significant others in determining the pre-competition goal state of junior tennis players. While no interaction effects were observed, the perceived state goal preference of significant others contributed to the prediction of the three state goals considered. The results of these studies taken together provided support for the important influence of significant others upon the goal states of junior athletes.

Socialisation

The goal orientations of children are reported to evolve as a result of their socialisation experiences within a particular achievement domain (Nicholls, 1989 op cit. Swain & Harwood, 1996; Duda, 1992, 1993a,b; White & Duda, 1994). The repeated interactions with significant others throughout the childhood years are hypothesised to shape the goal preferences of children in terms of dispositional goal orientations (Nicholls, 1989; Ames, 1992). Empirical studies have recently begun to examine the role of significant others in

the socialisation of children's goal orientations (Duda & Hom, 1993; Ebbeck & Becker, 1994; Peiro, Escarti & Duda, 1996). Duda & Hom (1993) examined the relationship between the perceived and self-reported goal orientations of children and their parents within the context of a summer basketball camp. The results indicated that parents were important socialising agents with the best predictor of the child's goal orientation being their perceptions of the goal orientation held by their most involved parent. This result, in combination with the absence of a significant relationship between the self-reported goal orientations of children and their parents, indicated that the child's perceptions may function to mediate the relationship between the self-reported goal orientations. It was also interesting to observe that the parents' perceptions of their children's goal orientation were more ego orientated and less task orientated than the self-reported values of children.

In a subsequent study, Ebbeck & Becker (1994) provided evidence in support of the important socialising role of parents in determining their child's goal orientations. From a number of hypothesised antecedents from social, environmental and personal sources, perceived parental goal orientations emerged as the most important predictor of the goal orientations of young female soccer players. However, two points of caution are raised concerning the interpretation of the results of these studies. Firstly, it may not be possible to directly compare the results across studies since the manner in which the perceptions of parental goal orientations were defined resulted in different modifications to the stem of the TEOSQ in the two studies. Specifically, Duda & Hom (1993) defined the perceived parental goal orientation in terms of the child's perceptions of when his/her *'parent'* feels most successful in the achievement activity (basketball). In contrast, Ebbeck & Becker's (1994) definition related to the child's perception of when the parents felt their *'child'* was most successful in soccer. Since parents have been suggested to construe competence in different ways for their children and themselves, inter-study comparisons may be of limited validity (Ebbeck & Becker, 1994). Secondly, Ebbeck & Becker (1994), citing the work of Felson (1989) highlighted the possibility that children's perceptions of their parents' goal orientations may in reality represent the child's reflection of the way in which they personally construe competence. Further support for the important role of significant others and in particular the role of parents and coaches may be derived from investigating the sources children used to evaluate their competence. The majority of such research has

been grounded within the theoretical framework of Harter's Competence Motivation Theory (Harter, 1978).

Development of competence information

There has been a general consensus in the literature that the sources children use to evaluate their physical competence change as a function of age (Horn & Hasbrook, 1986; Horn, Glenn & Wentzell 1993; Weiss, Ebbeck & Horn, 1997). Young children, less than eight years of age, were reported to rely primarily on adults to provide information about their competence. The feedback provided by parents was considered to be a particularly salient source of information through which young children are able to evaluate their competence (Horn & Hasbrook, 1986, 1987; Horn & Weiss, 1991; Brustad, 1996; Weiss et al., 1997). However, as children progress though late childhood into adolescence they become increasingly reliant upon peer comparison as a source of information about their competence (Weiss et al., 1997). The age-associated changes observed in children's preferences for information sources were attributed in part to changes in cognitive maturity, but were also suggested to reflect variations in the amount of time children spent in the company of adults and peers respectively (Brustad, 1996). While the study by Horn & Hasbrook (1986) observed age-associated changes in the sources used by children to assess their competence, considerable variability was observed within each age level. This led the authors to suggest that sport experience and the psychological characteristics of the athletes may influence preferences for particular sources of competence information (Horn & Hasbrook, 1986; Weiss et al., 1997).

Coaches have also been reported to play an important role in the development of children's perceptions of their competence (Smith, Smoll & Curtis, 1979; Horn, 1985; Black & Weiss, 1992; Brustad, 1996). Studies have applied modified versions of the coaching behavioural assessment scale (Smith et al., 1979) to determine the athletes' perceptions of coaching behaviours (Horn, 1985; Black & Weiss, 1992). In a study of junior softball players, Horn (1985) reported that certain coaching behaviours contributed to athletes perceptions of their physical competence over and above the contribution of skill level. Specifically, criticism and positive reinforcement were associated with higher and lower

levels of perceived competence respectively. While these results may appear surprising, they were interpreted to indicate the important relationship between changes in perceived competence and the extent to which feedback was interpreted to be contingent to the athletes' performance. In a subsequent study, Black & Weiss (1992) examined the relationship between feedback provided by coaches and various indices of intrinsic motivation in swimmers. In the older swimmers, adaptive motivational behaviours were observed when coaches provided feedback which could be classified as 'informational'. In contrast, in young swimmers 10-11 years of age there was no relationship between children's self-perceptions and the behaviour of their coaches. The absence of any relationship for the youngest subjects was suggested to reflect the inability of these children to differentiate between the concepts of effort, ability and task difficulty (Nicholls, 1978; Nicholls, 1984).

Given the reported association between achievement goals and the correlates of motivated behaviour, understanding the nature and development of dispositional goal orientations within the young female gymnasts may be considered a priority for research. Moreover, it will be important to understand the role of parents and coaches as potential socialisation agents influencing the development of dispositional goal orientations. It is unclear whether the gymnasts involved in the present study will be sufficiently advanced in terms of cognitive maturity to enable them to fully differentiate between the conceptions of effort and ability and thereby hold a state of ego involvement (Duda, 1993a,b). However, in light of the study by Fry & Duda (1997) which suggested that the differentiation of effort and ability may be accelerated in those children who participate in competitive youth sport programmes, the assessment of dispositional goal orientations within young female gymnasts was considered appropriate.

7.3 METHODS

Instrumentation

Dispositional goal orientations - Gymnast TEOSQ

The gymnasts' dispositional goal orientations were assessed using the British version of the Task and Ego Orientation in Sport Questionnaire (TEOSQ) (Duda et al., 1992). The TEOSQ is a 13 item inventory which is designed to assess an individuals disposition or 'proneness' to be task or ego involved in sport. The sub-scales of the TEOSQ have been reported to demonstrate adequate internal consistency (Duda, 1992; Boyd & Callaghan, 1994; White & Duda, 1994; Berlant & Weiss, 1997; Duda & Whitehead, 1998) and acceptable test-retest reliability over a three week measurement interval (Duda, 1992). The inventory comprises 13 items, six of which correspond to an ego orientation and seven of which correspond to a task orientation. Gymnasts were asked to think about when they most felt successful in gymnastics and respond to the stem "I feel most successful in gymnastics when...." by circling an appropriate response to indicate how much they agree or disagree with the 13 statements. The subjects responses were recorded on a five-point Likert scale from 1='strongly disagree' to 5='strongly agree'. Slight modifications were made to four of the items to make the language of the scale more consistent with the terminology used in gymnastic training (Appendix 7.1). For example, item nine was modified from 'I score the most points or goals' to 'I score the highest mark'.

Perceived parental goal orientations - 'Parentised' TEOSQ

The gymnasts' perception of their parents' dispositional goal orientations was assessed using a modified version of the Task and Ego Orientation in Sport Questionnaire, the 'parentised' TEOSQ. The gymnasts were asked to indicate which parent was most involved and responsible for their gymnastics. If gymnasts did not distinguish one parent as being responsible they were prompted to indicate which parent spent the greatest amount of time at gymnastic training and/or competitions. Gymnasts were asked to think about when they thought their parent felt they (*the gymnast*) were most successful in gymnastics and to respond to the stem "My mum/dad feels that I am most successful in gymnastics when...." by circling an appropriate response to indicate how much they agree

or disagree with the 13 statements. Identical modifications were made to the language of the TEOSQ as detailed above to enhance the specificity of the inventory to gymnastics (Appendix 7.2).

Perceived coach goal orientations - 'Coachised' TEOSQ

The gymnasts' perception of their coaches' dispositional goal orientations was assessed using a modified version of the Task and Ego Orientation in Sport Questionnaire, the 'coachised' TEOSQ. Gymnasts were asked to think about when they thought their coach felt they (*the gymnast*) were most successful in gymnastics and to respond to the stem "My coach feels that I am most successful in gymnastics when...." and circle an appropriate response to indicate how much they agree or disagree with the 13 statements. Identical modifications were made to the language of the TEOSQ as detailed above to enhance the specificity of the inventory to gymnastics (Appendix 7.3). To distinguish between the three versions of the TEOSQ and to facilitate the collation and processing of responses a system of colour coding was adopted.

Self-perception profile for children

Perceptions of competence were assessed using the Self-Perception Profile for Children (Harter, 1985). The questionnaire comprised six scales each containing six items which assess the degree to which individuals perceive themselves to be competent in the scholastic, social, athletic, physical (appearance), behavioural and global domains. The questionnaire items were organised in a structured alternative response format. Children were requested to initially choose which of two children they are more like. For example, 'some kids are *happy* with the way they look, but, other skids are *not* happy with the way they look'. They were then required to indicate whether this statement is 'sort of true' or 'really true' for them. The items relating to athletic competence (3, 9, 15, 21, 27 and 33) were modified to make them specific to gymnastics (Appendix 7.4). For example item 3 was modified from 'some kids do very well at all kinds of sports, but, other kids don't feel that they are very good when it comes to sport' to 'some gymnasts do very well on all pieces of apparatus, but, other gymnasts don't feel that they are very good when it comes to gymnastics'. Gymnasts were given adequate time to complete the questionnaire and a

member of the measurement team assisted by reading the statements aloud and helped the gymnasts to understand the format of the questionnaire. The items were scored with 1='low perceived competence' to 4='high perceived competence'. The total scores for each scale were summed and ranged from 6-24.

Sport enjoyment

Questions were selected to provide an affective measure of sport enjoyment in gymnastics. The adjectives 'fun' and 'enjoy' were considered to be consistent with the concept of sport enjoyment (Scanlan, Simons, Carpenter, Schmidt & Keeler, 1993). The concepts of sport enjoyment within training and competition were addressed separately according to the gymnasts' responses to the following questions:

Do you *enjoy* training in gymnastics?
Do you *have fun* training in gymnastics?

Do you *enjoy* competing in gymnastics?
Do you *have fun* competing in gymnastics?

Scores were derived for sport enjoyment in training and competition by averaging the questions relating to each concept.

Procedure

The completion of the psychological inventories was split between the two measurement sessions. Perceived competence and gymnastic enjoyment were assessed in the first rotation and the three goal orientation inventories were completed in the second session. Within the second measurement session the three versions of the TEOSQ were assigned to different testing stations separated by at least one intermediate activity and the order of the questionnaire stations was counterbalanced. Before completing each inventory, the gymnasts were informed that responses to the questionnaires were confidential and would not be passed on to coaches or parents. The gymnasts were assured that there were no right or wrong answers and were encouraged to answer the questions honestly. During

the completion of all inventories gymnasts were assisted by a member of the measurement team who read the questions aloud and clarified any problems with interpretation.

7.4 RESULTS

7.4.1 RELATIONSHIP TO FUTURE GYMNASTIC SUCCESS

Internal consistency

The results presented in Table 7.1 show that within the current sample of young female gymnasts the TEOSQ sub-scales representing the gymnasts' personal goal orientations demonstrated adequate internal consistency as indicated by an alpha value greater than 0.70 (Cronbach, 1951; Nunnally, 1978). This result confirms the results of previous studies which have reported adequate internal consistency for the TEOSQ sub-scales in samples of British children (Duda, et al., 1992; Fox et al., 1994) and In athletic samples including children less than 10 years of age (Duda & Hom, 1993). Adequate internal consistency was also observed for the sub-scales of the TEOSQ representing the gymnasts' perceptions of their coaches task and ego orientation and for the sub-scale representing perceived parental task orientation.

Table 7.1. Internal consistency for the TEOSQ sub-scales

	Task sub-scale	**Ego sub-scale**
Gymnast's GO	0.84	0.79
Perception of parental GO	0.75	0.67
Perception of coach GO	0.84	0.72

However, values reported for the sub-scale assessing the gymnasts' perception of the ego orientation of their most involved parent did not achieve the required level of internal consistency. This observation may reflect the cognitive developmental status of the gymnasts and may be interpreted to indicate that at least some members of the sample have

not yet attained a mature conception of ability and may therefore be unable to experience a state of ego involvement (Duda, 1993b).

Estimates of internal consistency were also obtained for the six sub-scales comprising the Self-Perception Profile for children (Harter, 1985). As shown in Table 7.2 the sub-scales representing the gymnasts' perceptions of scholastic, physical and behavioural competence demonstrated adequate internal consistency.

Table 7.2. Internal consistency for the sub-scales of perceived competence derived using the Self-Perception Profile for Children (Harter, 1985)

	Cronbach's (1951) alpha
Scholastic	0.72
Social	0.69
Gymnastic	0.62
Physical	0.74
Behavioural	0.74
Global	0.59

However, the social, gymnastic and global sub-scales failed to demonstrate adequate internal consistency according to the criterion of 0.70 proposed by Nunnally (1978). These results were surprising considering that the inventory was designed for children of a similar age to those involved in the present study. It was of particular concern that the sub-scale representing perceived gymnastic competence did not demonstrate adequate internal consistency given the modifications made to the language of the inventory in an attempt to enhance the relevance of the scale to young female gymnasts. The reasons for the low internal consistency observed for the social, gymnastic and global sub-scales are unclear but may be a function of the relatively small sample of gymnasts involved in the present study.

Descriptive statistics

The means, standard deviations and ranges for successful and unsuccessful gymnasts for each of the measurement sub-scales assessed in the present investigation are presented in Table 7.3.

Table 7.3. Descriptive statistics for sub-scales of psychological inventories

	Successful Mean ± SD (range)	**unsuccessful mean ± SD (range)**
TO (gym)	4.48 ± 0.38 (3.74-5.00)	4.18 ± 0.50 (3.00-5.00)
EO (gym)	3.47 ± 0.51 (2.67-4.17)	3.73 ± 0.86 (1.67-5.00)
PTO (par)	4.33 ± 0.47 (3.29-5.00)	4.24 ± 0.40 (3.43-4.86)
PEO (par)	3.56 ± 0.51 (2.50-4.17)	3.89 ± 0.60 (2.50-4.50)
PTO (coa)	4.08 ± 0.71 (2.29-5.00)	3.97 ± 0.42 (3.29-4.86)
PEO (coa)	3.29 ± 0.63 (2.00-4.50)	3.49 ± 0.69 (2.17-4.83)
Enjoy T	4.67 ± 0.39 (4.00-5.00)	4.69 ± 0.40 (4.00-5.00)
Enjoy C	4.17 ± 0.18 (3.50-5.00)	4.19 ± 0.14 (2.50-5.00)
Scholastic	2.97 ± 0.56 (2.00-3.67)	2.67 ± 0.48 (1.50-3.50)
Social	3.12 ± 0.57 (2.00-3.83)	3.15 ± 0.56 (1.83-4.00)
Gymnastic	2.75 ± 0.42 (2.33-3.67)	2.57 ± 0.51 (2.00-3.83)
Physical	2.93 ± 0.68 (1.17-3.83)	3.09 ± 0.54 (1.67-3.67)
Behavioural	2.26 ± 0.34 (2.83-3.83)	2.97 ± 0.48 (2.17-3.83)
Global	3.25 ± 0.39 (2.83-4.00)	3.20 ± 0.44 (2.33-3.83)

In line with the results of previous research, the self-reported task orientation of the gymnasts was greater than the self-reported values for ego orientation (Duda & Whitehead, 1998). The task orientation of the gymnasts involved in the present study was high, with all gymnasts scoring above 3.00 on the task sub-scale. This result confirmed the

observation of Harwood et al. (in press) that the majority of children agree with most items on the task sub-scale. This pattern of responses led Harwood et al. (in press) to question the validity of the task sub-scale with particular reference to its emphasis upon process goals and the failure of this sub-scale to adequately measure the self-referent nature of task orientation. It was also interesting to observed that the self-reported ego orientation of the gymnasts involved in the present study was higher than most previous estimates cited for children (Duda & Whitehead, 1998). Indeed, Duda & Whitehead (1998) reported the mean value of ego orientation for children less than 13 years of age to be 2.65 ± 0.86 compared with the values of 3.73 ± 0.86 and 3.47 ± 0.51 reported in the present study for successful and unsuccessful gymnasts respectively (Table 7.3). However, the results of the present study were more closely in line with the mean values reported in the literature for British children (Duda et al., 1992; Fox et al., 1994).

Correlational analysis

As shown in Table 7.4, the task and ego sub-scales representing the gymnasts' dispositional goal orientation were significantly correlated (r=0.441, p=0.010). A significant correlation was also observed between the gymnasts' perceptions of their coaches' task and ego orientations (r=0.479, p=0.005). These results were in contrast to observations reported in the majority of studies in both the academic and sporting domains which have consistently demonstrated the independence of task and ego sub-scales (Duda, 1989a; Duda, 1992; Berlant & Weiss, 1997). Moreover, these results do not support the hypothesis that task and ego goal orientations are orthogonal, which was an important assumption within the theoretical framework proposed by Nicholls (1984, 1989). This result may be interpreted to indicate that the gymnasts involved in the present study have not attained a fully differentiated conception of ability and are unable to experience a state of ego involvement (Duda, 1993b). The correlation between the gymnasts' perceptions of their parents' task and ego orientations was not significant (r=0.163, p=0.365). The gymnasts' self-reported task orientation was significantly correlated with their perceptions of the task orientation of both coaches (0.509, p=0.002) and parents (0.452, p=0.008). Similar levels of association were observed for the relationship between the gymnasts' self-

Table 7.2. The correlation matrix of gymnast's self-reported goal orientations, their perceptions of the goal orientations held by parents and coaches and the actual goal orientations held by parents and coaches

	TO (gym)	EO (gym)	PEO (par)	PTO (par)	PEO (coa)	PTO (coa)	AEO (par)	ATO (par)	AEO (coa)	ATO (coa)	PC (gym)	Enjoy T
EO (gym)	0.441*	—	—	—	—	—	—	—	—	—	—	—
PEO (par)	0.204	0.595**	—	—	—	—	—	—	—	—	—	—
PTO (par)	0.452**	-0.057	0.136	—	—	—	—	—	—	—	—	—
PEO (coa)	0.366*	0.744**	0.520**	0.079	—	—	—	—	—	—	—	—
PTO (coa)	0.506**	0.400*	0.137	0.509**	0.479**	—	—	—	—	—	—	—
AEO (par)	0.350	0.354	0.347	0.018	0.330	0.014	—	—	—	—	—	—
ATO (par)	0.528**	0.589**	0.413*	-0.102	0.436*	0.270	0.377	—	—	—	—	—
AEO (coa)	-0.062	-0.224	-0.116	-0.185	-0.315	-0.349	0.165	-0.025	—	—	—	—
ATO (coa)	0.209	0.543**	0.196	0.013	0.179	0.151	0.073	0.333	-0.247	—	—	—
PC (gym)	-0.146	-0.036	-0.170	-0.166	-0.070	0.001	-0.096	0.023	-0.097	0.187	—	—
Enjoy T	-0.052	-0.016	0.178	-0.098	-0.082	-0.029	-0.286	0.296	-0.251	0.290	0.016	—
Enjoy C	-0.143	0.050	-0.023	-0.052	-0.094	-0.037	-0.352	-0.230	0.162	0.339	0.053	0.365*

* significant at the 5% level
** significant at the 1% level

reported ego orientation and their perceptions of the ego orientation of their coaches (0.774, p=0.000) and parents (0.595, p=0.000). These results provided support for previous studies which have suggested that significant others play an important role as socialisation agents in shaping children's goal orientations (Duda & Hom, 1993; Ebbeck & Becker, 1994). It was interesting to observe that for both task and ego orientations, the correlation between the gymnasts' self-reported goal profile and their perception of the coaches' dispositional goal orientations was stronger than the correlation between the gymnasts' dispositional goal orientation and perceived parental goals. This was interpreted to indicate the important role of gymnastic coaches in shaping the goal orientations of their pupils. Significant correlations were also obtained between the gymnasts' task orientation and their perception of the coaches' ego orientation and between the gymnasts' ego orientation and their perception of the coaches' task orientation. These results were not consistent with theoretical expectations however, similar anomalies were also reported by Ebbeck & Becker (1994). In accordance with the theoretical predictions of goal perspective theory, perceived ability was not significantly correlated with the gymnasts' dispositional goal orientation or their perceptions of the goal orientations of coaches and parents. This is in agreement with previous research (Duda & Nicholls, 1992; Duda et al., 1995) and confirmed that the gymnast's perceptions of ability were not systematically related to the way in which they define success (Duda et al., 1995; Duda, 1989a, 1996).

The correlation matrix presented in Table 7.5 revealed that perceived gymnastic competence was not significantly associated with the other dimensions of perceived competence and was not significantly related to global self-concept. It was interesting to observe that the gymnasts' perceptions of their physical competence was significantly correlated with global self-concept highlighting the salience of physical appearance within the current sample of young female gymnasts.

Table 7.5. Correlation matrix for sub-scales of the self-perception profile (Harter, 1985)

	scholastic	Social	gymnastic	Physical	Behavioural
scholastic	----	----	----	----	----
Social	0.145	----	----	----	----
gymnastic	0.162	0.039	----	----	----
physical	-0.481 **	0.130	0.221	----	----
behavioural	0.490 **	-0.030	0.291	-0.022	----
global	-0.071 *	0.159	0.339	0.482 **	0.342

* significant at the 5% level
** significant at the 1% level

Logistic regression analysis

Logistic regression analyses were conducted to examine the relationship between selected psychological constructs and 'future' gymnastic performance. To control for the age differences between the successful and unsuccessful groups, decimal age was entered into each regression model as the sole independent variable in the first block. As previously reported, the inclusion of decimal age as the sole independent variable was associated with a significant reduction in the log likelihood (model $\chi^2 = 7.425$, p=0.006) but resulted in a relatively poor model fit (R^2_L of 0.172). The index of predictive efficiency (λ = 0.333, p=0.074) indicated that the inclusion of decimal age into the regression model was associated with a 33% reduction in classification errors when compared with a regression model including only a constant term. To examine the prognostic validity of psychological talent characteristics, the gymnasts' dispositional goal orientation and their perceptions of the goal orientations of significant others were standardised and entered into the regression model in the second block using forwards stepwise techniques. Any proposed interaction effects were computed and considered for inclusion in the third block of independent variables, again using stepwise entry methods. In line with previous chapters, an independent variable was included in the regression model if the change in the likelihood-ratio was statistically significant at the 20% level. However, in the discussion of the model, the contribution of independent variables was highlighted to be important if the

reduction in the log likelihood attained statistical significance at the 5% level. The degree of multicollinearity among the independent variables was estimated for each model using multiple linear regression analyses as detailed in Section 3.2. The range of tolerance values across all psychological models was 0.393-0.947 all of which were above the critical threshold of 0.20 and therefore indicated that the level of multicollinearity within the data was acceptable to proceed with the logistic regression analyses (Menard, 1995).

Model 1: Dispositional goal orientation and perceived gymnastic competence

The first regression model examined the main and interactive effects of the gymnasts' self-reported goal orientation and perceived gymnastic competence upon future gymnastic success. The standardised mean sub-scale scores for task orientation, ego orientation and perceived gymnastic competence were entered into the logistic regression model in the second block. In line with the theoretical predictions of goal perspective theory, the interaction between the standardised variables of ego orientation and perceived gymnastic competence was computed and entered into the logistic regression model in block three.

$$\text{Logit(selected)} = 1.2063(\text{zdecage}) - 1.4251(\text{zgymego}) + 1.5042(\text{zgymtask}) - 1.0565$$

As shown in the equation above future success in gymnastics was associated with a dispositional proneness toward a high task and low ego orientation. These results were consistent with the findings of previous empirical studies which reported that high levels of task orientation were associated with the demonstration of adaptive motivational behaviours within achievement situations (Duda, 1992, 1996). The interaction between the gymnasts' self-reported ego orientation and perceived gymnastic competence did not attain statistical significance at the 20% level and was therefore not included in the regression model. Therefore, the present investigation failed to derive support for the hypothesised role of perceived ability as a mediating construct between dispositional goal orientation and achievement behaviour defined in terms of future gymnastic success (Nicholls, 1984, 1989; Roberts, 1984).

The significant reduction in the log likelihood associated with the variables entered in block two indicated that the fit of the model to the observed data was enhanced by the inclusion of the independent variables (block $\chi^2 = 7.211$ (16.7%), p=0.027 and R^2_L=0.338).

Table 7.6. Classification table for the logistic regression model including dispositional goal orientation and perceived gymnastic competence

	Unsuccessful	successful	correct
Unsuccessful	19	2	90.5%
Successful	5	7	58.3%
		overall	79.8%

However, as shown in Table 7.6 the small change in predictive efficiency (λ = 0.417, p=0.035) indicated that the improvement in classification accuracy associated with the inclusion of these variables was relatively minor.

Model 2: Gymnasts' ego orientation and perceived parental goal orientation

Following the forced entry of decimal age in the first block, the ego orientation of the gymnast and their perceptions of the goal orientation of their most involved parent were considered for inclusion into the regression model. Finally, the computed products of these independent variables were entered in block three using stepwise techniques to examine the interaction effects of these variables upon the future performance of young female gymnasts.

Logit(selected) = 1.1772(zdecage) - 0.9639(zparego) – 0.7625(zgymego * zparego) – 1.0565

The negative coefficient associated with the gymnasts' perceptions of their parents ego orientation indicated that the probability of future success in gymnastics was increased when gymnasts perceived their parents to hold a low ego orientation. In addition, the interaction term between the ego orientation held by the gymnast and the gymnasts'

perception of their parents' ego orientation was also significant and was included in the regression model. The fit of the model was moderate (R^2_L=0.272), however, as shown in Table 7.7 the reduction in the log likelihood associated with the inclusion of the psychological constructs in blocks two and three did not attain statistical significance at the 5% level (block 2, $\chi^2 = 2.542$ (5.9%), p=0.111 and block3, $\chi^2 = 1.792$ (4.1%), p=0.181). Moreover, as shown in Table 7.8, the model did not improve classification accuracy above that which could be achieved using decimal age as the sole independent variable ($\lambda = 0.333$, p=0.074).

Table 7.7. Results of the logistic regression model including gymnasts' ego orientation and perceived parental goal orientation

	B	block χ^2	Significance
decimal age	1.1772	7.425	0.006**
zparego	-0.9639	2.542 (5.9%)	0.111
zgymego*zparego	-0.7625	1.792 (4.1%)	0.181

* significant at the 5% level
** significant at the 1% level

Table 7.8. Classification table for the logistic regression model including gymnasts' ego orientation and perceived parental goal orientation

	Unsuccessful	successful	Correct
unsuccessful	17	4	81.0%
successful	4	8	66.7%
		overall	75.8%

Therefore, it may be concluded that the psychological constructs included within this regression model are of limited use in distinguishing between successful and unsuccessful gymnasts. However, it is important to examine the nature of the interactions between the ego orientation of the gymnast and their perception of the ego orientation of the parent most involved in supporting their gymnastics. The graphical representation technique,

described by Swain & Harwood (1996) within the context of multiple linear regression, was applied to examine the interaction effects described above. Logit equations were produced which corresponded to two levels of the gymnasts' perceptions of their parents' ego orientation. This manipulation was achieved by changing the mean value of the perceived parental ego orientation by ±1 standard deviation to reflect perceptions of a parent low in ego orientation (-1 standard deviation) and high in ego orientation (+1 standard deviation). The effects of this manipulation are presented in Figure 7.1 for gymnasts demonstrating low (-1 standard deviation) and high (+1 standard deviation) ego orientations. In Figure 7.1 the probabilities of success were derived from the logit equation as outlined in Section 3.2. The points on the graph were joined using dashed lines to represent the non-linear nature of the logistic function.

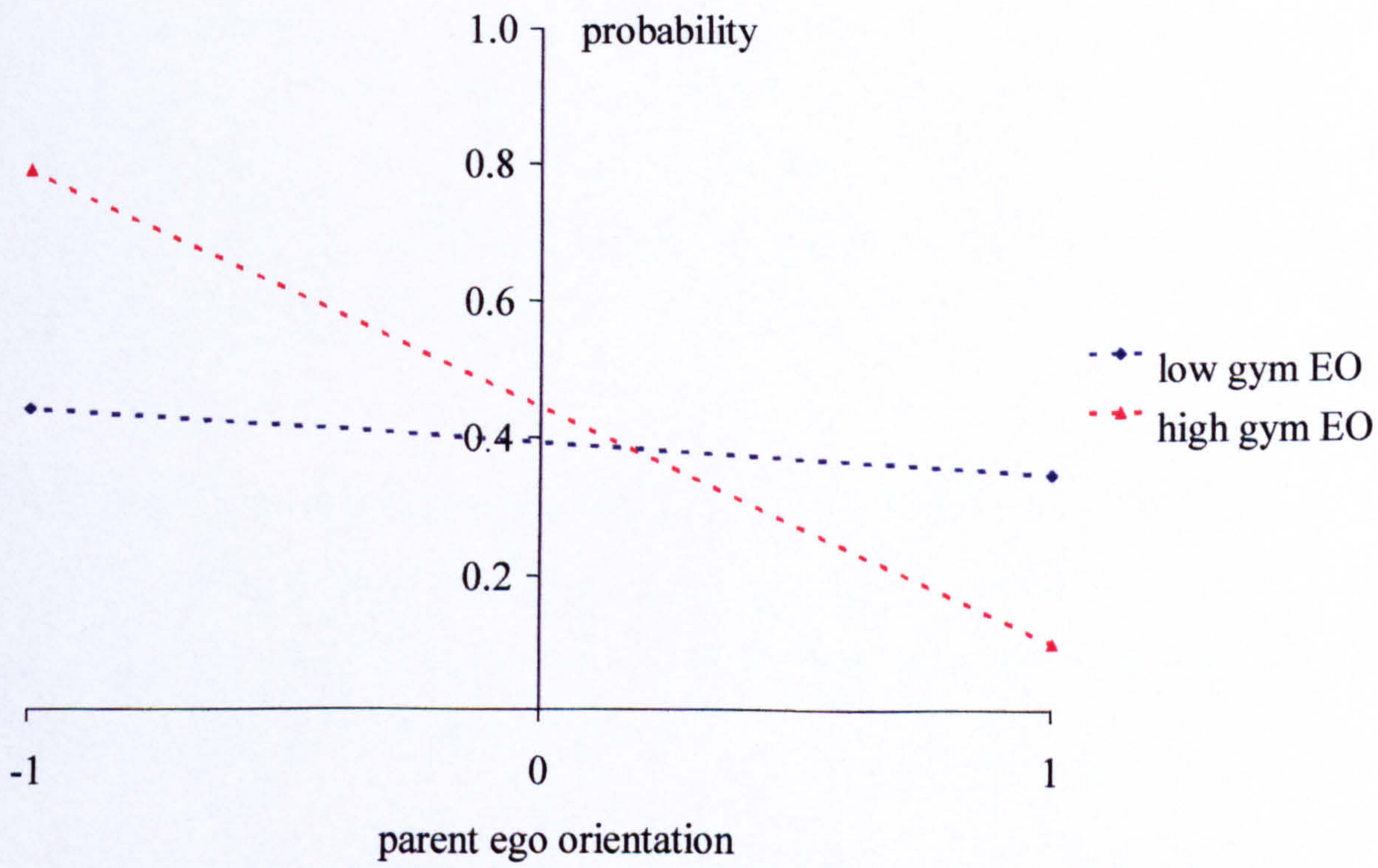


Figure 7.1. Interaction effect of gymnasts' ego orientation and gymnasts' perception of parents' ego orientation on the probability of future success in gymnastics.

Figure 7.1 highlights the extent to which gymnasts' perceptions of their parental ego orientation influenced the probability of achieving future gymnastic success according to the dispositional goal orientation held by the gymnast. For example, for those gymnasts who held a low ego orientation, their perceptions of the ego orientation of their parents had a minimal influence upon the probability of future success. In contrast, the gymnasts'

perceptions of the ego orientation held by their parents had a much greater impact upon the probability of future gymnastic success for those gymnasts who were high in ego orientation. Figure 7.1 indicates that the young female gymnasts who held a high ego orientation and who also perceived their parents to be high in ego orientation had the lowest probability of future success. It may be hypothesised that such children have few opportunities to construe their ability positively in the face of failure and/or low perceived competence. This result was consistent with two studies cited by Duda (1996) which reported that motivational problems are most likely to occur when a strongly ego orientated individual is placed in an strongly ego orientated environment (Andree & Whitehead, 1995; Newton & Duda, 1995 op cit. Duda, 1996). This result indicates the importance of the situational antecedents of goal orientation and highlights the need for parents to be aware of the consequences associated with their projected goal orientations. It was interesting to note that the greatest probability of future success was observed in those gymnasts who held a high ego orientation but who perceived their parents' ego orientation to be low. This result provides support for those who advocate the positives associated with ego goals when accompanied by a high task orientation or in the presence of high perceived ability (Fox et al., 1994; Hardy, 1997, 1998).

Model 3: Gymnasts' task orientation and perceived parental goal orientation

The third regression model examined the association between the gymnasts' task orientation, their perceptions of parental goal orientations and the respective interaction effects upon future performance in gymnastics.

$$\text{Logit(selected)} = 1.0283(\text{zdecage}) - 0.9970(\text{zparego}) + 0.9516(\text{zgymtask}) - 0.8996$$

In line with the tenets of goal perspective theory, the results of the regression model presented above indicated that future gymnastic success was associated with a high level of self-reported task orientation and a low perceived parental ego orientation. There were no significant interactions between the independent variables. The fit of the model was moderate $R^2_L = 0.300$ (block χ^2=5.576 (12.9%), p=0.082) however, in comparison to

decimal age only one additional gymnast was correctly classified (λ = 0.417, p=0.035) (Table 7.9).

Table 7.9. Classification table for the logistic regression model including gymnasts' task orientation and perceived parental goal orientation

	unsuccessful	Successful	correct
unsuccessful	18	3	85.7%
successful	4	8	66.7%
		Overall	78.8%

Model 4: Gymnasts' ego orientation and perceived coach goal orientation

Following the forced entry of decimal age in the first block, the ego orientation of the gymnast, and their perceptions of the dispositional goal orientation of their coach were considered for inclusion into the regression model. Finally, the product of these independent variables was entered using stepwise techniques to examine the interaction effects in relation to future performance in gymnastics.

$$\text{Logit(selected)} = 1.5409(\text{zdecage}) - 1.1656(\text{zpcoaego}) - 0.9284(\text{zgymego} * \text{zpcoaego}) - 0.4129$$

The results of this model were in line with those presented for model two (ego orientation and perceived parental goal orientation). The negative coefficient associated with the gymnasts' perceptions of their coaches' ego orientation indicated that success in gymnastics was associated with perceptions that the coach held a low ego orientation. The interaction term between the ego orientation of the gymnast and the gymnasts' perception of their coaches' ego orientation was also significant and was included in the regression model. The fit of the model was moderate (R^2_L=0.303), however, the reduction in the log likelihood associated with the inclusion of the independent variables in blocks two and three did not attain statistical significance at the 5% level (block 2, $\chi^2 = 3.153$ (7.3%), p=0.076 and block3, $\chi^2 = 2.524$ (5.8%), p=0.112). Although the regression model was similar in structure to model two, classification accuracy was improved for the present

model (Table 7.10) with the predictive efficiency indicating a reduction in classification errors of almost 60% when compared to the model including a constant term only (λ = 0.583, p=0.006).

Table 7.10. Classification table for the logistic regression model including gymnasts' ego orientation and perceived coach goal orientation

	Unsuccessful	Successful	Correct
Unsuccessful	19	2	90.5%
Successful	3	9	75.0%
		Overall	84.9%

Table 7.11. Results of the logistic regression model including gymnasts' ego orientation and perceived coach goal orientation

	B	Block χ^2	significance
Decimal age	1.5409	7.425	0.006**
Zpcoaego	-1.1656	3.153	0.076
Zgymego*zpcoaego	-0.7625	2.524	0.112

* significant at the 5% level
** significant at the 1% level

The interaction effects were represented graphically as previously outlined for model 2. It is clear from Figure 7.2 that the gymnasts' perceptions of the coaches' ego orientation moderated the dispositional ego orientation of the gymnast in a similar manner to the results presented in Figure 7.1. Specifically, when the ego orientation of the gymnast was low, their perception of the ego orientation of the coach had little impact upon the probability of future success. In contrast, when the ego orientation of the gymnast was high their perception of the coaches' level of ego orientation had a much greater impact upon the probability of future success. Although the nature of the relationship was similar to that observed for the gymnasts' perception of their parents ego orientation (Figure 7.1),

the strength of the interaction effect was more pronounced in the present model (Figure 7.2). The strength of this interaction effect may be expected when the nature of Women's Artistic Gymnastics is considered and in particular the large volume of training experienced by young female gymnasts and the considerable amount of time spent in contact with the coach. Moreover, as a result of the restrictions many gymnastics clubs place upon parental access to and/or observation of training, the influence of the perceived goal (ego) orientation of the coach over and above that of the parent may be expected within this particular achievement domain.

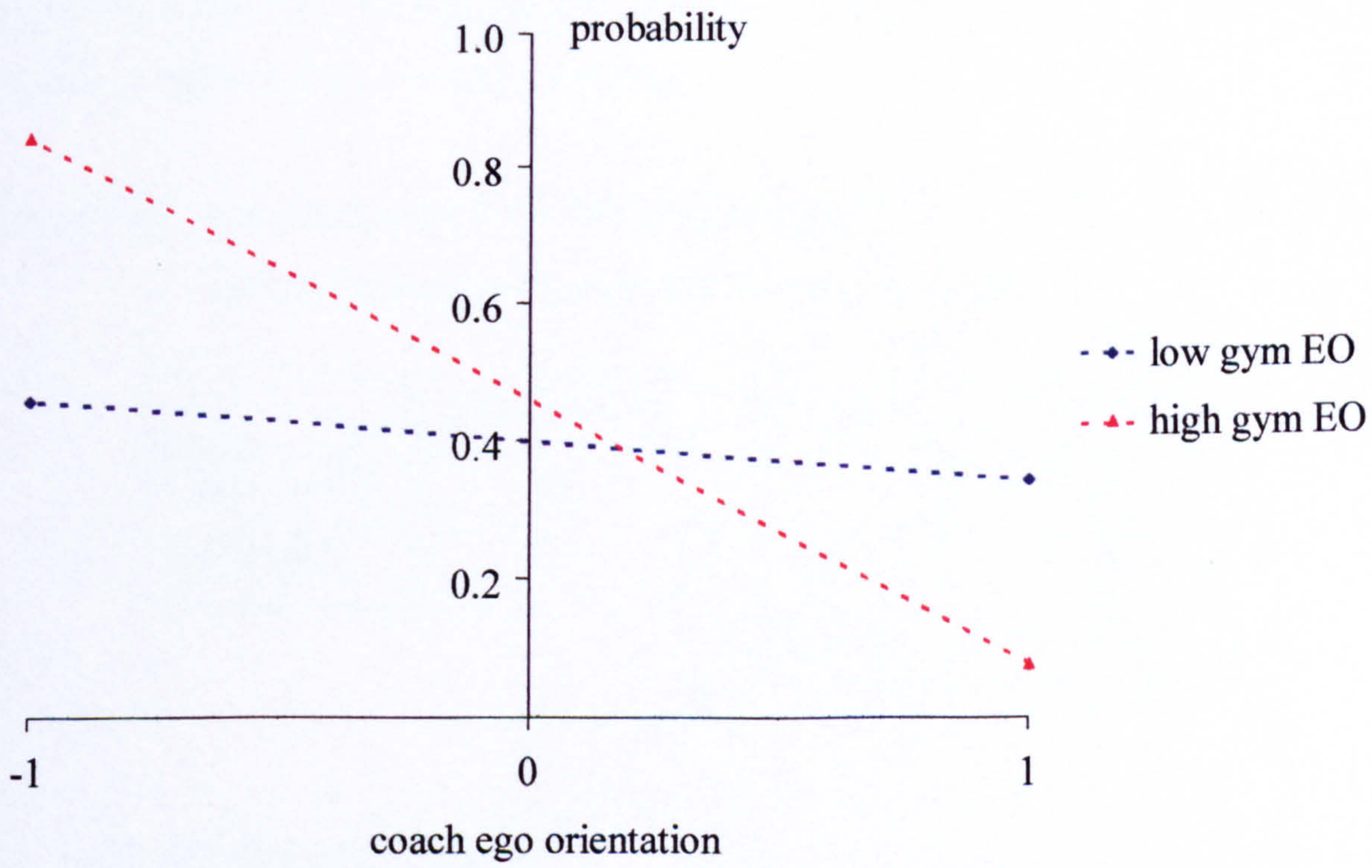


Figure 7.2. Interaction effect of gymnasts' ego orientation and gymnasts' perception of coaches' ego orientation on the probability of future success in gymnastics.

Model 5: Gymnasts' task orientation and perceived coach goal orientation

The fifth model examined the association between the gymnasts' task orientation, the gymnasts' perceptions of the coaches' goal orientation and the interaction effect of these constructs upon the probability of future success in gymnastics.

$$\text{Logit(selected)} = 1.4684(\text{zdecage}) - 1.2874(\text{zcoaego}) + 1.1473(\text{zgymtask}) - 1.0697$$

In line with the findings presented for model 3, two main effects were observed which were consistent with the results of previous empirical studies which adopted a dispositional approach to the study of achievement goals. Firstly, the gymnasts' perceptions of the coaches' ego goal orientation was associated with a negative coefficient indicating that successful gymnasts perceived their coaches to be low in ego orientation. Secondly, successful gymnasts were associated with a relatively high task orientation in comparison with their less successful peers. The fit of the model was moderate ($R^2_L = 0.333$), and the reduction in the log likelihood associated with the main effects included within block two was statistically significant at the 5% level (block χ^2=7.000 (16.2%) p=0.030). Moreover, as shown in Table 7.12 the classification accuracy of the model was good with only four gymnasts misclassified ($\lambda = 0.667$, p=0.002).

Table 7.12. Classification table for the logistic regression model including gymnasts' task orientation and perceived coach goal orientation

	unsuccessful	Successful	Correct
Unsuccessful	19	2	90.5%
Successful	2	10	83.3%
		Overall	87.9%

7.4.2 LONGITUDINAL STABILITY

Dispositional goal orientations

The longitudinal stability of the disposition or proneness of a gymnast to adopt a particular goal orientation was assessed using rank order autocorrelations.

Table 7.13. Longitudinal stability of gymnasts' dispositional goal orientations

	zTO(gym)	
	time 2	time 3
time 1	0.603**	0.613**
time 2	----	0.658**

	zEO(gym)	
	time 2	Time 3
Time	0.686**	0.449*
Time	----	0.535**

There is little information in the literature concerning the longitudinal stability of dispositional goal orientations. According to the classification proposed by Malina (1996b), task orientation appeared to be highly stable over the 12 month period of measurement with the rank order autocorrelations in excess of 0.60 for each measurement interval. The autocorrelations for ego orientation were moderate to high but tracked slightly less consistently than task orientation. The greater temporal instability of the ego goal may reflect the cognitive development of the gymnasts and specifically, changes in the ability of gymnasts to differentiate between the concepts of effort and ability.

Perceptions of parental goal orientations

Table 7.14. Longitudinal stability of perceived parental goal orientations

	zPEO(par)	
	time 2	time 3
Time	0.475*	0.402
Time	----	0.557

	zPTO(par)	
	time 2	time 3
Time	0.448*	0.471*
Time	----	0.541**

The gymnasts' perceptions of parental goal orientations were moderately stable over time and the strength of the correlations was similar across all measurement intervals. Only minor differences were observed between the stability of gymnasts' perceptions of their parents' task and ego goal orientations respectively.

Perceptions of coach goal orientations

The autocorrelations for the gymnasts' perceptions of their coaches' goal orientations demonstrated greater variability than either the self-reported goal orientations of the gymnasts or their perception of parental goals. The reasons for this increased variability are unclear however, they are hypothesised to reflect the changes in training groups which occur periodically as gymnasts become older and more proficient. It was interesting to note that the greatest variability was associated with the gymnasts' perceptions of the coaches' task orientation. This variability may be cause for concern given that previous

studies have consistently cited the importance of promoting task involvement (Duda, 1996).

Table 7.15. Longitudinal stability of perceived coach goal orientations

	zPEO(coa)	
	time 2	time 3
time 1	0.457*	0.342
time 2	----	0.671**

	ZPTO(coa)	
	time 2	time 3
Time	0.341	0.107
Time	----	0.737**

7.5 DISCUSSION

The task orientation of the gymnasts in the present study (4.48±0.38, successful and 4.18±0.50, unsuccessful) was similar to the mean value reported by Duda & Whitehead (1998) for eight samples of children under 13 years of age (4.24±0.58). In contrast, the ego orientation of the present sample of gymnasts was high (3.47±0.47, successful and 3.73±0.86, unsuccessful) in relation to this reference group (2.65±0.86). Relative to their personal disposition, the gymnasts perceived their parents to hold a similar task orientation and their coaches to a hold lower task orientation. The gymnasts also perceived their parents to have a higher level of ego orientation in relation to their own personal disposition and their coaches to be less ego orientated. In summary, when compared to a reference sample, the gymnasts could be described as a high task, higher ego group who, relative to their own disposition, perceived their parents to be higher in ego orientation and their coaches to be lower in both task and ego orientation.

Fry & Duda (1997) suggested that children who participated in competitive sport from a young age may experience an accelerated progression with respect to the differentiation of effort and ability and may demonstrate more mature levels of reasoning in comparison with age matched controls. Therefore, it was assumed that given the age of the gymnasts and the number of years they had been participating in gymnastics, their conceptions of ability would be at or approaching maturity. However, the correlation between the gymnasts' dispositional task and ego orientations was statistically significant at the 5% level

(p=0.010) indicating evidence of non-orthogonality. A similar correlation was also observed between the gymnasts' perceptions of their coaches' task and ego orientations (r=0.479, p=0.005). These results were interpreted to indicate that at least some of the gymnasts in the present sample did not hold a fully mature conception of ability and may therefore be unable to experience a state of ego involvement (Duda, 1993).

In the first regression model, the gymnasts' dispositional goal orientations and their perceptions of gymnastic competence were included in the second block, with the interaction between the gymnasts' ego orientation and perceived gymnastic competence entered in the third block. The sign of the regression coefficients confirmed the trends evident within the descriptive data presented in Table 7.3. The results revealed that within the present sample, future success in gymnastics was associated with higher levels of task orientation and lower levels of ego orientation. Moreover, since standardised decimal age was entered into the regression model in the first block, these results could not simply be attributed to the differences in chronological age between successful and unsuccessful gymnasts. It is acknowledged that a profiling approach will be required to determine the combination of task and ego goals most closely associated with success in young female gymnasts. However, the results of this model did not provide support for the suggestion that a High Task-High Ego (HiT, HiE) goal profile may be the most desirable combination of achievement goals within the young female gymnast.

In contrast to theoretical predictions, the reduction in the log likelihood associated with the interaction between perceived gymnastic competence and ego goal orientation did not attain significance at the 20% level and therefore this item was not included within the regression model. Two possible reasons may be forwarded to explain the absence of the interaction effect. Firstly, it is possible that the cognitive immaturity of the gymnasts may preclude the significance of the interaction term. Specifically, if some of the gymnasts within the sample were unable to fully differentiate between effort and ability and were therefore unable to experience a state of ego involvement (Duda, 1993) the interaction between perceived gymnastic competence and gymnastic-specific competence would not be expected to achieve statistical significance. Secondly, it is also possible that limitations associated with the measurement of perceived gymnastic competence and in particular the low internal consistency reported in Table 7.2 may limit the validity of the regression

model. The internal consistency of the perceived gymnastic competence sub-scale remained unacceptable when each item was systematically removed from the scale. This was taken to indicate problems of interpretation with the entire sub-scale rather than reflecting problems with a single item.

The second and fourth models described in Section 7.4.1 were similar in structure and included variables relating to the gymnasts' ego orientation and their perceptions of the dispositional goal orientation adopted by their parents and coaches respectively. The main effect terms indicated that in relation to their less successful peers, successful gymnasts perceived the goal orientations held by the significant others to be lower in ego orientation. The nature of the interaction between the gymnasts' ego orientation and their perceptions of the parent/coach ego orientation may have important implications for the organisation of talent development. Specifically the gymnasts' perceptions of the parents/coach ego orientation had little impact upon the probability of future gymnastic success when the gymnast themselves had a low ego orientation. In contrast, when the gymnasts had a strong disposition towards ego involvement the gymnasts' perceptions of their parent/coaches' ego orientation had a large impact upon the probability of achieving future success in gymnastics (Figure 7.1).

It was particularly interesting to observe that the combination of high personal ego orientation and perceptions of a high ego orientation of significant others resulted in the lowest probability of future success. The observation confirmed the findings of two studies cited by Duda (1996) which reported that the likelihood of motivational problems were enhanced when the individual's disposition and the environment in which they function are both strongly ego involving (Andree & Whitehead, 1995; Newton & Duda, 1995 op cit. Duda, 1996). Furthermore, it was interesting to observe that the probability of future success was greatest when the gymnast was strongly ego orientated and perceived the ego orientation of significant others to be low. Therefore, in addition to contentions that strong ego goals may not be detrimental when combined with high task goals or with high perceptions of ability (Hardy, 1997, 1998) such goals may not be detrimental to future performance when the dispositional ego orientation of significant others is perceived to be low. It may therefore be concluded that gymnasts who define their performance according to normative criteria are more likely to achieve future success

when significant others within their training and home environments de-emphasise ego goals. This result provides support for those who suggest that the adoption of ego goals is not necessarily detrimental to performance.

Several reasons may be proposed to explain why the impact of the goals held by significant others appears to have a particularly salient effect upon the probability of future success in this sample of young female gymnasts. Firstly, it has been suggested that the goal orientations of young children are not fully formulated and may be particularly susceptible to the influence of the motivational climate (Roberts & Treasure, 1992). Fry & Duda (1997) contended that the transition between levels three and four in the developmental progression towards a mature conception of ability may be a sensitive or 'critical' period in which the gymnast develops a proneness for a particular goal profile. It is likely that the gymnasts in the present study were at or around this transition during the initial measurement session. Finally, the role of significant others may be considered particularly important in the young female gymnast given the developmental differences reported in the sources of information used by children to evaluate their competence (Horn & Hasbrook, 1986; Horn et al., 1993; Weiss et al., 1997).

Although, models two and four were similar in nature, gymnasts' perceptions of the goal orientation held by their coach had a greater impact on future performance than their perceptions of the ego orientation held by the most involved parent. This result confirms the important role of the coach and highlights the need for coaches to pay close attention to their coaching strategies and the feedback they provide to gymnasts in response to both successful and unsuccessful performances. The influence of the coach may be particularly salient within the present sample given the large number of training hours completed by the gymnasts each week and the exclusive access of coaches to the achievement situation.

The third and fifth models described in Section 7.4.1 included the gymnasts' task orientation and their perceptions of the goal orientations adopted by their parents and coaches respectively. The third and fifth regression models were similar in structure and distinguished between successful and unsuccessful gymnasts with a high level of classification accuracy. Within these models, future success in gymnastics was associated

with a high self-reported task orientation and perceptions that the coach and/or most responsible parent held a low ego orientation.

The results of those regression models which included gymnasts' perceptions of the goal orientations held by significant others indicated the positive benefits of de-emphasising ego goals, thereby reducing the extent to which gymnasts perceived parents and coaches evaluated their competence according to normatively referenced criteria. The results of these models suggested that within the present achievement context de-emphasising the gymnasts' perceptions of ego goals may be more important than positively emphasising their perceptions of task goals.

It is clear from the present study that the gymnasts' perceptions of the goal orientation held by significant others has an important influence upon the probability of future success. However, it is important to emphasise the mediating role of the gymnasts' perceptions. The relationship between parents' actual goal orientation and the gymnasts' perceptions of their parents' goal orientation has not been conclusively determined. The study by Duda & Hom (1993) was the first to investigate the nature of this relationship and indicated that the personal goal orientations held by parents were not significantly related to their child's perceptions of their parents' goal orientation ($r=0.11$ and 0.08, $p>0.05$ respectively). However, as previously discussed the results of the Duda & Hom (1993) study were of limited validity given the manner in which the stem of the TEOSQ was modified.

Within the present study, data were collected from the parents and coaches to determine their actual goal orientation which was defined in terms of when they felt their child was most successful in gymnastics. The poor completion rate of the parental and coach inventories precluded these data from being included in the main analyses. However, it is evident from the correlations presented in Table 7.16 that no consistent relationships could be observed between the actual goals held by the gymnasts and/or coaches and the gymnasts' perceptions of these goal orientations. It is possible that the absence of significant relationships is due to the limited sample size compounded by the poor response rates of parents and coaches. However, these data provide support for the important role of the child's perceptions in mediating the relationship between their personal goal orientation and the dispositional goal orientation held by significant others.

Table 7.16. Correlations between the actual and perceived goal orientations of significant others

	AEO (par)	ATO (par)
PEO (par)	0.347	0.413*
PTO (par)	0.018	-0.102

	AEO (coa)	ATO (coa)
PEO (coa)	-0.315	0.179
PTO (coa)	-0.349	0.151

* significant at the 5% level
** significant at the 1% level

Several possible explanations may be forwarded to account for the lack of a relationship between the actual goal orientations of parents/coaches and the gymnasts' perceptions of parental/coaches' goal orientations. Firstly, as suggested by Felson (1989) op cit. Ebbeck & Becker (1994) rather than perceiving the actual goal orientation held by parents and/or coaches, the gymnasts may be reflecting their personal goal orientations upon significant others. Secondly, it may be hypothesised that the communication of goals by significant others may be poor which may result in children misinterpreting these goals (White, Duda & Hart, 1992). It is also possible that the significant others involved in the present study responded to the TEOSQ in a socially desirable manner. Although Duda (1992) reported that neither of the TEOSQ sub-scales significantly correlated with social desirability, the possibility that coaches and/or parents responded to the TEOSQ to portray a particular self-image cannot be rejected. Indeed, during the completion of the TEOSQ, several of the gymnasts indicated that some of the items within the ego sub-scale were 'not nice things to say'. It may also be speculated that although significant others believed they were providing accurate responses to the TEOSQ their responses were not consistent with the manner in which they actually construed the competence of their gymnasts. Observations of coaches' responses during training and in particular during competition provided tentative support for this contention. Several of the coaches who reported a strong task orientation were observed to provide feedback consistent with a state of ego involvement during competition. The 'first past the post system' through which gymnasts are selected to enter the U12 and Junior National Squads may induce coaches to experience high levels of ego involvement during pre-competition and competition periods which may have a particularly salient impact upon the young gymnasts' perceptions.

The final contribution of the present section concerned the longitudinal stability of the goal orientations over the 12 month period of study. In general the gymnasts' self-reported goal orientations and their perceptions of the goal orientations held by significant others were high to moderately stable. A certain degree of temporal instability was observed for the ego goals which was interpreted to reflect the progression of gymnasts towards attaining a mature conception of ability. The gymnasts' perceptions of their coaches' task orientation was associated with the greatest instability which was speculated to result from gymnast's working with a number of different coaches during the early stages of their gymnastic careers.

7.6 SUMMARY

A summary of the results of the five logistic regression models produced within the psychological dimension is provided in Table 7.17. The table presents estimates of the predictive efficiency (λ), model fit (R^2_L model) and the reduction in the log likelihood associated with the main effect terms (block χ^2).

Table 7.17. A summary of the results of the logistic regression analyses conducted within each category of the psychological dimension

	lambda (λ)	d	p	Block χ^2 (%)	P	R^2_L model
Model 1	0.417	1.809	0.035 *	7.211 (16.7)	0.027 *	0.338
Model 2	0.333	1.447	0.074			0.272
(block 2)				2.542 (5.9)	0.111	
(block 3)				1.792 (4.1)	0.181	
Model 3	0.417	1.809	0.035 *	5.576 (12.9)	0.082	0.300
Model 4	0.583	2.533	0.006 **			0.303
(block 2)				3.153 (7.3)	0.076	
(block 3)				2.524 (5.8)	0.112	
Model 5	0.667	2.895	0.002 **	7.000 (16.2)	0.030 *	0.333

* significant at the 5% level
** significant at the 1% level

For models two and four, separate estimates are provided for the reduction in the log likelihood associated with both main effects (χ^2 block 2) and interaction terms (χ^2 block 3). The fit of the regression models within the psychological dimension of performance was moderate and demonstrated greater consistency than the models produced within physical and perceptual-motor dimensions. In addition, the psychological regression models classified the future performance of gymnasts as successful or unsuccessful with a level of accuracy that was comparable with the models produced within the physical and perceptual-motor dimensions of performance.

Within the first regression model, future success in gymnastics was positively related to the gymnast's level of task orientation and negatively related to their level of ego orientation. However, in contrast to theoretical predictions, the model failed to provide support for the mediating role of perceived ability upon the relationship between ego orientation and future gymnastic performance. The subsequent regression models examined relationships between future gymnastic performance, gymnasts' goal orientation and gymnasts' perceptions of the goal orientation held by parents or coaches. The results of these models indicated that future success in young female gymnasts was negatively related to gymnasts' perceptions of the level of ego orientation held by their parents and coaches.

Interaction terms were included in the second and fourth regression models and consisted of the interaction between the gymnast's ego orientation and their perceptions of the level of ego orientation held by their parents or coaches. The impact of these interaction terms upon future gymnastic performance was examined using the graphical representation techniques described by Swain & Harwood (1996). A similar pattern of results was observed irrespective of whether the interaction term included the gymnasts' perception of the goal orientation held by their parents or coaches. Specifically, when the ego orientation of the gymnast was constrained to be low (one standard deviation below the sample mean) variations in the gymnast's perceptions of the ego orientation held by significant others had a minimal influence upon the probability of future success. In contrast, when the ego orientation of the gymnast was constrained to be high (one

standard deviation above the sample mean) the gymnasts' perceptions of the ego orientation held by significant others had a marked effect upon future performance.

The highest probability of future success was predicted for those gymnasts who held strong ego goals and perceived their parents and/or coaches to hold a low ego orientation. The observation that the ego orientation of the gymnast was positively related to future success in gymnastics was in contrast to the results obtained within the first regression model and provided support for contentions that strong ego goals are not necessarily detrimental to performance (Swain & Harwood, 1996; Hardy, 1997, 1998). Several authors have cited the importance of adopting multiple goals to provide alternative sources of competence information and thereby contributing to preserve competence and provide an alternative source of satisfaction in the event that normatively referenced competence is threatened (Harwood & Swain, 1996; Duda, 1997; Hardy, 1997, 1998). However, the results of the present study indicated that the gymnasts' perceptions of the task orientation held by their parents and/or coaches did not appear to function as a secondary source of satisfaction which could complement the personal goal orientation held by the gymnast. A marked decrease in the probability of future success was predicted when the strongly ego orientated gymnast perceived their parents and/or coaches to hold a strong ego orientation. It was speculated that maladaptive motivational consequences and associated achievement behaviour which are theorised to occur when with the ego involved gymnast is unsure of her ability may be compounded when the gymnast perceives that significant others are also evaluating her competence according to comparisons with a normative referent.

It is therefore concluded that gymnasts' perceptions of the goal orientations held by their parents and coaches have an important influence upon the achievement motivation and future performances of young female gymnasts. The graphical representation techniques employed within the present investigation indicated that the gymnasts' perceptions of the level of ego orientation held by their coaches had a more pronounced effect upon future performance when compared with the gymnasts' perceptions of the goal orientation held by their parents. It is also clear from Table 7.17 that the greatest classification accuracy was observed within the fourth and fifth regression models, both of which included the gymnasts' perceptions of the goal orientations held by their coaches. Therefore, it is

recommended that coaches, in particular, exercise caution when evaluating the competence of their gymnasts and when designing training strategies and providing feedback within the achievement domain.

It is also noteworthy that within the present study there did not appear to be any clear relationship between the self-reported goal orientations held by parents and/or coaches and the gymnasts' perceptions of these goal orientations. Therefore it is recommended that future research is conducted to elucidate the nature of these relationships and to investigate the mechanisms through which children formulate their perceptions of the goal orientations held by significant others. It is anticipated that in light of such research guidelines may be established concerning the coaching strategies and feedback mechanisms most likely to encourage positive achievement behaviour and future success in young female gymnasts.

The present study was associated with two main limitations, both of which need to be addressed in the design of future research. Firstly, the present investigation was constrained by the size of the 'gymnasts only' sample. Therefore, one priority for future research will be to replicate the present study to determine whether the relationships observed can be confirmed within a larger sample of young female gymnasts. Moreover, a larger sample of gymnasts will permit the scope of the research to be extended to include a consideration of goal profiles. It is recommended that within this larger sample, a more detailed examination of the relationship between the self-reported goal orientation of the gymnast and their perceptions of the goal orientations held by significant others is undertaken and that the effects of a three-way interaction are examined. The second major limitation concerned the suggestion that some of the gymnasts involved in the present study may have lacked the cognitive maturity required to fully differentiate between the concepts of effort and ability and were consequently unable to experience a state of ego involvement (Duda, 1993b). Therefore, it is recommended that future research is directed towards examining the longitudinal development of achievement goals within the young female gymnast in order to determine the most appropriate age to introduce assessments of goal orientation. In line with the concerns raised regarding the developmental issues and the sensitive ethical concerns which surround the identification of talent it is recommended that the psychological constructs assessed within the present research are not considered

for inclusion within the battery of tests designed to identify gymnastic talent. However, it is recommended that the development of these characteristics is monitored on a regular basis throughout the career span of the young female gymnast and that such information is used to inform the process of talent development.

CHAPTER 8

SUMMARY & DISCUSSION

According to a recent survey of Performance Directors and Sports Scientists, talent identification is the number one priority for research within Great Britain (Burwitz, 1999). While the ability to identify talented performers from a young age may be inherently appealing in the majority of sports, it may be considered an essential pre-requisite for success in highly technical sports such as gymnastics. Moreover, the need for talent identification may be considered particularly salient in Women's Artistic Gymnastics in which the finite career span of the elite performer requires a structured training programme of technical preparation to be commenced from a relatively young age. In the absence of a systematic process of identification, young and potentially talented children may fail to experience the sport at an early enough age to permit the realisation of their potential.

The systematic identification of talent was accorded primary importance in the programmes of gymnastic development operating within nations of the former Eastern bloc. More recently, systems of identification have been adopted with varying degrees of success by Western nations. However, despite its popularity, the contribution of talent identification to the attainment of international excellence has not been conclusively determined. The present research sought to examine the potential efficacy of talent identification by determining the extent to which initial talent characteristics were able to predict future performance in young female gymnasts. In addition, the research sought to determine the most appropriate combination of talent characteristics to be included in the initial identification of talent and those which should be monitored at subsequent stages of the development process. This chapter will discuss the results and observations of the present study in the context of previous research and the organisation of international systems. As a result, recommendations will be proposed regarding the establishment of a multidimensional system of talent identification and development within Great Britain.

The current research was conducted in accordance with several philosophical assumptions. The initial identification of talent was assumed to be only the first stage in a continuous

process of development through which expert performance may be acquired as a result of the long term interaction between innate individual differences and environmental stimuli. It was also assumed that the talent process is a complex multidimensional phenomenon which encapsulates the essence of human individuality and the dynamic nature of talent development. Therefore, the design of the study and the interpretation of results embodied an awareness that the developmental status of children is continually changing in terms of both physical and cognitive maturity. In light of these assumptions, the motivation of the present research was to extend knowledge and understanding of the talent process by investigating the relationship between talent characteristics and future gymnastic performance. The study also sought to examine the longitudinal development of these characteristics within the context of the training programmes completed by the young female gymnast. It is anticipated that the enhancement of understanding may facilitate the establishment of a system through which children who demonstrate talent may be identified and nurtured in a supportive environment.

The present research was designed in accordance with the recommendations for future research outlined by Burwitz et al. (1994) and sought to address the three main purposes outlined in Chapter 1:

[a] To investigate the relationship between talent characteristics and future performance in young female gymnasts.

[b] To determine which talent characteristics are able to differentiate between gymnasts and untrained controls.

[c] To provide an insight into the longitudinal development of talent characteristics and their stability and sensitivity to development in the context of gymnastic training.

The research was exploratory in nature and therefore the initial objective was to reduce the large number of potentially prognostic talent characteristics identified within four dimensions of performance to a smaller number of reliable talent components. The extent to which the talent components were able to predict future gymnastic performance and

correctly classify gymnasts as successful or unsuccessful on the basis of their future performance was determined using logistic regression analyses. To estimate the potential contribution of talent components to the initial identification of talent, similar analyses were performed with children classified as gymnasts or untrained control subjects. To address the final purpose of the research, the longitudinal development of talent characteristics was examined over a 12 month period thereby providing an insight into the stability of the talent characteristics and their potential sensitivity to development within the context of gymnastic training.

Throughout the study it was acknowledged that the process of talent identification and development is a multidimensional phenomenon with the profile of the young female gymnast best described using a combination of talent characteristics from social-demographic, physical, perceptual-motor and psychological dimensions of performance. However, given the exploratory nature of the research and the differences expected in the relative strength of prediction between dimensions it was felt that the greatest insight could be obtained by considering the contribution of each dimension separately. The results revealed that each dimension of performance provided a unique and yet complementary contribution to the identification and development of talent. For example, the physical and perceptual-motor characteristics were analysed using a predominantly quantitative approach and were found to be the most important indicators of future performance in terms of the initial identification and subsequent monitoring of gymnastic development. The predominantly qualitative analysis of the social-demographic data indicated that the major contribution of these characteristics was to inform the structure and organisation of the talent process. Finally, using a combination of quantitative and qualitative techniques, the analysis of psychological characteristics provided important information regarding the goal orientation of young female gymnasts and the potential influence of parents and coaches upon the achievement behaviour of young female gymnasts.

In the following sections, the contribution of talent characteristics within each dimension of performance will be summarised together with specific recommendations for future research. However, several general findings will initially be presented which concern the global organisation of the talent process. Firstly, it was observed that a different combination of talent characteristics best distinguished between groups within 'pooled'

and 'gymnasts only' samples. While it is acknowledged that the 'pooled' sample does not accurately represent the status of children at the point of initial identification, these findings were interpreted to confirm the multi-stage nature of the talent process (Jarver, 1981; Régnier & Salmela, 1987; Hartley, 1988; Karacsony, 1988; Linderholm & Simon, 1988; Fisher & Borms, 1990; Mashi & Xhang, 1995; Stan, 1995). It was also observed that in terms of the relationship between initial talent characteristics and future gymnastic performance, the physical and perceptual-motor talent characteristics distinguished between successful and unsuccessful gymnasts with a similar level of classification accuracy. However, the physical characteristics demonstrated a marked improvement in classification accuracy using the more heterogeneous 'pooled' sample which was not observed for the perceptual-motor characteristics. In addition to the classification accuracy of the talent characteristics, their longitudinal stability was taken into account when selecting those characteristics to be included in the initial identification and/or the systematic monitoring of gymnasts. The results suggested that while a combination of physical and perceptual-motor characteristics may be useful in monitoring talent development, it is the physical talent characteristics which have the greatest prognostic validity in the initial identification of talent.

Social-demographic talent characteristics

The contribution of social-demographic talent characteristics was interpreted within the framework for talent development proposed by Bloom (1985) with reference to the three phases inherent within this framework. In line with the results of previous research, the entry of gymnasts into the sport was characterised by chance opportunities rather than the result of any systematic process of talent identification. The children and their parents as primary socialisation agents, were predominantly responsible for the decision to commence gymnastics. Therefore, it may be anticipated that a large number of potentially talented children may fail to experience gymnastics as a result of a lack of parental awareness regarding gymnastics and the opportunities for participation within the local community. It is therefore concluded that British Gymnastics may benefit from a National system of talent identification through which opportunities may be presented to those children who demonstrate a talent for gymnastics. However, it is recommended that identification

programmes should be initiated in those geographical areas which possess a sound programme of talent development, with screening programmes encompassing existing recreational programmes and primary schools within the local community.

The retrospective accounts published by Bloom (1985) and Hemery (1991) highlighted the important role of the 'early years' in providing a positive experience through which a long-term commitment may be nurtured. The importance of stimulating the child's interest in the sport was also recognised to be an important role of the probationary training periods which were incorporated into a number of international systems (Fisher & Borms, 1990; Mashi & Xhang, 1995). Previous studies indicated that the interpersonal characteristics of the initial coach and specifically his/her ability to work with young children were of paramount importance in stimulating enjoyment and interest and thereby encouraging the development of a long term commitment to the sport (Bloom, 1985; Carlsson & Engstrom, 1988 op cit. Fisher & Borms, 1990). It was also observed that the majority of coaches who worked with expert performers in their early years were proficient teachers of basic skills, although for most performers this was largely the result of chance (Bloom, 1985). Given the highly technical nature of Women's Artistic Gymnastics, it is recommended that a high level of technical proficiency is established from a young age. However, it will be important that the basic skills are introduced in a manner which is fun, enjoyable and conducive to fostering a long term commitment. Therefore, the selection of coaches to work with the young female gymnasts, once identified, will be critical to their ultimate success. Moreover, it will also be essential that these coaches are provided with the appropriate training and support to enable them to develop the balance of social and technical skills necessary to ensure that young female gymnasts are provided with an optimal experience in their early years.

It is recommended that gymnasts are identified and guided towards Women's Artistic Gymnastics at approximately five to six years of age. Given this relatively early 'specialisation' it will be essential to formulate training programmes in relation to the developmental status of the child with particular reference to their readiness to acquire skills. Therefore, it is considered most appropriate that training in the 'early years' resembles a form of structured play in which children are encouraged to participate in enjoyable activities which provide a broad range of motor experiences. Such an approach

will be essential since at this young age many of the physiological systems have yet to reach maturity, which may indicate the child's apparent 'unreadiness' for specialisation. For example, the development of balance ability was reported to be in a state of transition between four to six years of age with an apparent regression observed as the young child attempts to integrate information from the various sensory systems. It may be anticipated that over-emphasis in training upon a single component of balance may limit the effectiveness of this transition and may ultimately restrict the development of a mature level of balance ability. It is therefore recommended that increased specialisation accompanies the onset of more systematic training as gymnasts enter the competition structure at seven to eight years of age.

The research by Bloom (1985) clearly highlighted that coaches were required to possess a different balance of technical and inter-personal skills in each phase of talent development. It is anticipated that few coaches will be able to provide the necessary expertise and social skills across the entire career span and therefore, for many expert performers a team of coaches may be best able to provide support at each phase of the development process. This is in contrast to the system of talent development currently operating within British Gymnastics in which gymnasts traditionally remain with the same coach throughout their gymnastic career. It is therefore recommended that within a formal system of talent identification and development several coaches work together in a team to prepare and support the gymnasts. Such an approach will demand a high level of cooperation within the coaching team with careful management of the transition periods in which gymnasts are required to adapt to new coaching staff. For such a system to succeed, modifications will be required to the existing reward scheme and specifically a greater acknowledgement of the contribution of coaches working with the gymnasts in the early phases of talent development. It is proposed that this may be accomplished by increasing the status of these coaches to acknowledge the complexity of the developmental issues with which they must be familiar.

The importance of the practical and emotional support of the family has been confirmed in a number of studies of young athletes and highlights the need to establish regionally based systems of identification and development with centralisation taking place only towards the latter stages of a gymnast's career (Bloom, 1985; Hemery, 1991; Carlson & Engstrom,

1988 op cit. Fisher & Borms, 1990; Fisher & Borms, 1990). The important role of parents in supporting their children's gymnastic activities has traditionally been neglected by coaches, with many choosing to restrict parental access to the training facility. However, given the important influence of parents and in particular the critical distinction between parental support and parental pressure (Bloom, 1985; Hemery, 1991; Carlson & Engstrom, 1988 op cit. Fisher & Borms, 1990) it is recommended that within the National system of talent identification and development a programme of education is made available to all parents to inform them on how to best support their children's gymnastic pursuits.

The results of the logistic regression analyses did not provide support for the role of deliberate practice in determining expert performance. Both the total number of training hours per week and the cumulative years of participation and/or systematic training were unable to distinguish between successful and unsuccessful gymnasts. The absence of a relationship was surprising, however, it was speculated that this may be due to the lack of a detailed description of the training stimulus and in particular the omission of indices relating to the intensity of training. These results were interpreted to indicate that the absolute duration is not an important factor in determining the future success of young female gymnasts. Moreover, the range of training hours reported by gymnasts involved in the present study (10-36 hours per week) indicated that several gymnasts were completing in excess of the training hours recommended by British Gymnastics and that such gymnasts may benefit from a reduction in the total number of hours and a greater emphasis upon the quality and intensity of training. It is also possible that the absence of a relationship between training hours and future gymnastic performance may reflect the technical nature of the sport and provide support for the hypothesis that the attainment of excellence is the result of a long term interaction between the profile of the gymnast and environmental stimuli.

The results indicated that financial and travel demands did not restrict the participation of the gymnasts involved in the present study. However, it is a feature of their level of involvement in the sport that the parents of these gymnasts were able and willing to accommodate the cost of their sporting pursuits. It is speculated that financial and travel demands are most likely to limit the involvement of children at the initial stage of

identification. Safeguards in the form of scholarships will be required to ensure that opportunities for talented gymnasts to participate in talent development programmes are not restricted by the financial status of their parents.

In conclusion, the major contribution of talent characteristics within the social-demographic dimension was to inform the structure and organisation of talent development. The results of the present study indicated that a person related model of talent identification and development is currently operating within Women's Artistic Gymnastics. In such a model talent emerges as a result of the participation of children in recreational programmes with the necessary support structures available to develop talent once it has emerged (Fisher & Borms, 1990). It is suggested that this development programme would be enhanced if a formal system of talent identification was introduced thereby providing a continuous pathway through which talented gymnasts may progress from the initial identification of talent through to the attainment of international excellence. More detailed recommendations concerning the structure of the proposed system are provided in the proposal for 'World Class Start' submitted for consideration by the English Sports Council (Prescott, 1999, unpublished).

Physical talent characteristics

Physical talent characteristics from the categories of anthropometry, body composition, moment of inertia, isometric strength, jumping and flexibility were associated with a high level of measurement reliability. The results of principal components analysis and logistic regression revealed that within each physical category a small number of talent components distinguished between successful and unsuccessful gymnasts with a high level of classification accuracy. When the prognostic indicators from each category were combined into a further regression model a 'perfect fit' was detected indicating that a unique solution could not be obtained. It was therefore concluded that more than one linear combination of the talent components would result in the future performance of all gymnasts in the present sample being correctly classified as successful or unsuccessful. The 'all possible subsets' approach revealed that linear combinations of three physical components, anthropometry (frame shape/size), local muscular endurance (abdominal and

hip flexor muscle groups) and flexibility (hip and shoulder regions) were responsible for producing the perfect fit. A marked improvement in classification accuracy was observed for the sample of gymnasts and controls which was attributed to reflect the greater heterogeneity of the 'pooled' sample. Within the 'pooled' sample a 'perfect fit' was obtained within the physical categories of jumping and flexibility which precluded the prognostic physical components from being combined to produce a physical model. Differences in the structure of the test battery and the results of the principal components analyses prevented a direct comparison between samples. However, it was apparent that a different combination of prognostic talent components best distinguished between groups in the 'pooled' and 'gymnasts only' samples. These results provided support for a multistage approach to talent identification, indicating that a different combination of talent components should be included in the initial identification and at subsequent stages of the development process.

The purpose of the initial screening battery was to identify from a large sample of children those individuals who have the potential to demonstrate future success in Women's Artistic Gymnastics. Therefore, a small number of talent characteristics were sought which could be practically administered in a mass screening situation, were appropriate for administration to five to six year old children and demonstrated high predictive validity and longitudinal stability. According to the results of the logistic regression analyses conducted within the 'pooled' sample, the following physical talent characteristics are recommended for inclusion in the initial identification battery subject to confirmation via an appropriate pilot study:

anthropometry:	mass, height, biacromial width, biiliac width, epiphyseal widths, predicted adult height
jumping:	normalised standing broad jump
flexibility:	seated fold, shoulder flexion, 'D' shape
local muscular endurance:	situps (30 s)

In light of the results of the logistic regression analyses conducted for the 'gymnasts only' sample, two types of physical characteristics were considered for inclusion into a system for monitoring talent development within the young female gymnast. Firstly, those physical characteristics which distinguished between successful and unsuccessful gymnasts with a high level of classification accuracy but demonstrated low levels of stability. Although such characteristics may be considered important predictors of future performance, they are sensitive to environmental stimuli and therefore have the potential to be modified through training. For example, the results of the logistic regression analyses revealed that while the component representing the isometric rate of force development in the shoulder region was associated with future gymnastic performance the longitudinal stability of this component was low and demonstrated considerable inconsistency. The poor tracking of this component was primarily attributed to inter-individual differences in the training stimulus.

It was also considered important to monitor the development of a second set of physical talent characteristics, which were sensitive to the growth and maturation of the child. Whilst these characteristics do not necessarily contribute to the prediction of future performance, their development may have implications for the acquisition and maintenance of gymnastic skills and/or the development of associated talent characteristics. For example, a previous study which examined the longitudinal development of moment of inertia within the growing child highlighted the enhanced sensitivity of this characteristic to changes in physical maturity in comparison with traditional indices of growth such as height and weight (Jensen, 1981). It will be important for coaches to be aware of the impact of the changes in whole body moments of inertia upon the ability of a gymnast to successfully execute rotational skills and the psychological consequences which may result when previously mastered skills become increasingly difficult to complete. Therefore, it is recommended that whole body moments of inertia and the corresponding moment of inertia ratios are monitored annually during the prepubertal years with twice yearly measurements conducted throughout puberty. A complete list of the physical talent characteristics recommended for inclusion in a system of monitoring is presented below:

anthropometry:	mass, height, sitting height
moment of inertia:	whole body moments of inertia and inertia ratios
isometric strength:	maximal isometric force (shoulder flexion/hip extension) maximal rate of force development (shoulder flexion/hip extension)
jump:	patterns of force application in the counter movement jump
flexibility:	seated fold, shoulder flexion, 'D' shape, dynamic flexibility (hip) and active hip flexion,
local muscular endurance:	abdominal/hip flexors, lower extremity, lumbar region

Additional points of interest emerged during analysis of physical talent characteristics which merit further discussion. The results initially obtained within the jumping category were in contrast to theoretical expectations and highlighted the limitations associated with the use of statistical techniques to predict future gymnastic performance in the absence of a sound theoretical understanding. The results of the logistic regression suggested that future success in gymnastics was associated with lower power production in the bounce drop jump which was clearly in contrast to theoretical expectations. However, a closer examination of drop jump performances revealed that successful and unsuccessful gymnasts adopted different jumping strategies which approximated the counter drop and bounce drop jump styles described by Bobbert et al. (1986). The observation that different drop jump styles were adopted was suggested to account for the relationship obtained between gymnastic performance and lower extremity power and highlights the need for further research to be directed towards the development of reliable field-based assessments of rebound ability.

Questions were also raised concerning the application of linear models to examine the relationship between physical talent characteristics and future gymnastic success. For example, the results of the logistic regression analyses indicated that while gymnasts could be distinguished from untrained controls on the basis of their smaller physical size and/or skeletal frame, the successful gymnasts possessed a relatively large skeletal frame in relation to their less successful peers. Therefore, it appears that success in gymnastics is associated with a specific skeletal frame which although small is sufficiently robust to withstand the impulsive nature of the sport and the demands placed upon the upper and lower extremities. Hence, a smaller skeletal frame is associated with a greater probability of success up to a point after which further reductions in frame size are associated with a reduced probability of future success. Linear combinations of talent components may be considered appropriate to model future performance within 'pooled' and 'gymnasts only' samples. However, when the goal is to identify those gymnasts with the potential to be successful from a random sample of the general population, which is the ultimate goal of a talent identification system, a non-linear function may most accurately represent the relationship between anthropometric talent components and future gymnastic success.

It is recommended that future research is conducted to determine the extent to which higher order terms may enhance the predictive validity of physical characteristics, with specific reference to anthropometric and flexibility talent components. Further investigation will also be required to establish a test protocol for the assessment of the gymnasts' rebound ability since in the present study the protocol used in the assessment of the bounce drop jump was not sufficient to produce a true measure. It is also suggested that data relating to predicted adult height is obtained from age matched control subjects to determine the role of this characteristic in the initial identification of talent. At the present time accurate prediction of adult height requires invasive measures of skeletal maturity. It is recommended that as non-invasive estimates become increasingly available their validity is established within samples of young female gymnasts so that they may be used in the prediction of adult height. Finally, it should be established whether including measurements of dynamic strength, which more closely represent gymnastic activities than the isometric assessments used in the present study, may enhance the accuracy with which successful gymnasts may be distinguished from their less successful peers.

Perceptual-motor talent characteristics

Despite careful attention being paid to the design of the assessments, the poor level of measurement reliability was a major concern within the perceptual-motor dimension of performance. As a result, several characteristics which were intuitively related to future performance were excluded prior to the logistic regression analyses. Within the 'gymnasts only' sample, perceptual-motor characteristics distinguished between successful and unsuccessful gymnasts with a level of accuracy which was equivalent to that reported for the physical talent characteristics. The most prognostic indicators of future gymnastic performance were those characteristics representing timing accuracy and postural steadiness in DO, DC and SO stances. When similar analyses were conducted using the 'pooled' sample, only dynamic balance and timing accuracy were reported to distinguish between gymnasts and untrained controls. Moreover, the marked increase in classification accuracy observed when the physical talent characteristics were assessed in the more heterogeneous 'pooled' sample was not apparent within the perceptual-motor dimension. The relative lack of improvement was attributed to the poor measurement reliability of perceptual motor characteristics and the lack of sway data within the sample of untrained control subjects.

Based upon the results of the present study it is recommended that timing accuracy and assessments of postural steadiness are included within the system of monitoring gymnastic development. While timing accuracy distinguished between groups in both 'pooled' and 'gymnasts only' samples, it is suggested that the assessment may not be appropriate for inclusion within the initial identification battery. Specifically, it was anticipated that the very young children involved in the initial identification process may lack the cognitive maturity required to comprehend and/or execute the demands of the timing task. In addition, given the low to moderate stability of timing accuracy it is recommended that further research is conducted to examine the longitudinal development of this characteristic in order to establish the most appropriate stage to commence monitoring.

The results of the logistic regression analyses indicated that, for the majority of sway components, future success in gymnastics was associated with greater postural steadiness. However, several components within the double leg stance conditions indicated that the

successful gymnasts may be adopting alternative strategies to maintain postural steadiness in the medial-lateral direction. Specifically, the cumulative frequency distributions observed within DO and DC stance conditions indicated that the successful gymnasts used higher frequency oscillations to maintain steadiness when compared to their less successful peers. It was speculated that these high frequency oscillations may reflect the superior ability of successful gymnasts to detect and respond to movements of the mass centre away from the base of support which may result from specific training programmes associated with balance beam performance. However, the contribution of these strategies to the maintenance of postural steadiness was not conclusively determined, with a reduction in the standard deviation of medial-lateral sway reported for successful gymnasts only in the DO stance. Therefore, it is recommended that further research is conducted to confirm the presence of these strategies within a larger sample of female gymnasts with attention directed to determine the underlying mechanisms responsible for the high frequency oscillations observed within the successful gymnasts.

As a result of the sophisticated data capture system the assessments of postural steadiness employed within the present investigation are not suitable for inclusion within the initial identification battery. Moreover, the age at which talent is identified within Women's Artistic Gymnastics coincides with the apparent regression of balance ability which occurs as young children begin to integrate information from various sensory systems at approximately four to six years of age. However, it is recommended that future research is conducted to examine the longitudinal development of postural steadiness with particular emphasis placed upon the development of strategies to maintain balance within gymnasts and age-matched, untrained control subjects.

In summary, the contribution of perceptual-motor characteristics was severely constrained by the poor measurement reliability associated with these characteristics. Therefore, it is recommended that future research is directed towards improving the assessment of perceptual-motor talent characteristics with particular emphasis placed upon enhancing the reliability of kinesthetic talent characteristics and devising more challenging assessments of reaction time and dynamic balance.

Psychological talent characteristics

A series of logistic regression models were produced to examine the influence of selected psychological constructs upon the future performance of young female gymnasts. The selection and analysis of psychological talent characteristics were based upon the developmentally-based goal perspective theory of achievement motivation proposed by John Nicholls (Nicholls, 1984, 1989). In contrast to the social-demographic, physical and perceptual-motor dimensions in which only the main effects of talent characteristics were examined, the theoretical framework adopted within the psychological dimension permitted a consideration of both main and interaction effects.

Results of the five hierarchical regression models produced within the psychological dimension confirmed several relationships proposed within goal perspective theory. The first model indicated that success in gymnastics was positively related to the gymnast's level of task orientation and negatively related to the strength of their ego orientation. This result provided support for recommendations citing the active promotion of a task orientation and the de-emphasis of ego goals. However, in contrast to theoretical predictions, the present study failed to find support for the mediating role of perceived competence upon the relationship between dispositional goal orientation and future gymnastic performance.

The second and fourth regression models revealed that the goal orientation held by significant others was related to the future performance of young female gymnasts. However, this relationship was mediated by the gymnast's perceptions of the goal orientation held by their parents and/or coaches. The sign of the regression coefficients indicated that successful gymnasts perceived their parents and coaches to be less ego orientated in comparison with the perceptions of their less successful peers. The interaction terms were examined using graphical representation techniques and revealed that gymnast's perceptions of the goal orientation of their parents and/or coaches had a minimal impact upon future performance when the gymnast's level of ego orientation was constrained to be low (one standard deviation below the sample mean). However, when the gymnast's level of ego orientation was constrained to be high (one standard deviation above the sample mean), the gymnast's perceptions of the goal orientation held by

significant others had a large influence upon the probability of future success. The highest probability of future success was observed for those gymnasts with a strong ego orientation who perceived their parents and/or coaches to have a low ego orientation. Therefore, in contrast to observations from the first regression model, these results provided support for recent suggestions that a high ego orientation is not necessarily detrimental to sporting performance (Hardy, 1997, 1998). The lowest probability of future success was observed for those gymnasts with a strong ego orientation who perceived their parents and/or coaches to hold a high ego orientation. It is speculated that the maladaptive achievement behaviour which results when the ego involved individual is unsure of his/her ability is compounded when they perceive that significant others are also construing their competence according to their ability to demonstrate superior performance over others. Finally, the third and fifth regression models examined the association between the gymnast's task orientation, their perceptions of parental/coach goal orientation and the respective interaction effects upon future performance in gymnastics. The results indicated that future success was associated with a high level of self-reported task orientation and low perceived parental ego orientation. No significant interaction effects were observed.

The regression models constructed within the psychological dimension classified the future performance of successful and unsuccessful gymnasts with a similar level of accuracy to those produced within the physical and perceptual-motor dimensions. The fourth and fifth regression models, which included gymnast's perceptions of the goal orientation held by their coaches, were associated with the greatest increases in predictive efficiency. These results highlighted the need for parents and in particular for coaches to be aware of the potential influence their goal orientation may have upon the future performance of young female gymnasts and to exercise caution when evaluating the competence of their gymnasts. No consistent relationships were observed between the actual goals held by the gymnasts and/or coaches and the gymnasts' perceptions of these goal orientations. Therefore it will be important to further investigate the nature of this relationship in order that guidelines may be established concerning the coaching strategies and feedback mechanisms most likely to encourage positive achievement behaviour and future success in young female gymnasts. Finally, in terms of explained variance, the contribution of the

psychological constructs was generally lower than that observed within the physical and perceptual-motor dimensions.

As a result of the limited size of the 'gymnasts only' sample it is recommended that further research is conducted to confirm the relationships observed within the present study using a larger sample of gymnasts and to extend the present research to include an examination of goal profiles. It will also be important to apply both quantitative and qualitative techniques to examine the nature and development of gymnast's dispositional goal orientations and the development of their perceptions of the goal orientations held by significant others. One of the major limitations of the present study concerned the observation that some of the gymnasts may have lacked the cognitive maturity necessary to fully differentiate between the concepts of effort and ability and were therefore unable to experience a state of ego involvement (Duda, 1993). It will therefore be necessary to examine the longitudinal development of achievement goals within the young female gymnast in order to determine the most appropriate age at which to introduce the assessment of goal orientation. In line with these developmental considerations and the sensitive ethical concerns which surround the identification of talent it is recommended that the psychological constructs assessed within the present research are not considered for inclusion within the battery of tests designed to identify gymnastic talent. However, it is recommended that the development of these characteristics is monitored throughout the career span of the young female gymnast and that such information is used to inform the process of talent development.

Implications for talent identification and development

The present research was exploratory in nature and sought to reduce the large number of characteristics measured within the initial test battery to a smaller number of prognostic talent components which may be included in a system of talent identification and development. In accordance with the practical concerns which surround the initial identification of talent, assessments were designed to be simple to administer to permit the measurements to be obtained within a programme of mass screening. However, since the present research was also concerned with furthering understanding of the talent process,

where simple, reliable assessments were unavailable, more complex assessments were included within the research design. For example, traditional field-based assessments of static balance were not considered to be sufficiently sensitive to detect subtle relationships with future gymnastic performance and were therefore replaced with more sophisticated assessments of postural sway derived using platform posturography.

From the results of the present study it may be concluded that there are a number of talent characteristics within the young female gymnast which are essential to future performance and which remain relatively stable over the life-span of the gymnast irrespective of the training stimulus. It is recommended that these 'critical antecedents', which were derived predominantly from the physical dimension, should form the basis of the initial identification system. A number of additional talent characteristics were also identified as prognostic indicators of future gymnastic performance which demonstrated lower longitudinal stability and were therefore more susceptible to modification by the application of an appropriate training programme. It is recommended at the present time that a profile is produced on the basis of these characteristics to highlight the strengths and weaknesses of the child and thereby inform the structure and organisation of the training process. It is recommended that future research is commissioned to provide information on the development of these characteristics within young female gymnasts with specific attention directed to establish the extent to which each characteristic may be modified through an appropriate training programme.

As a clearer understanding of the development of these talent characteristics is obtained it may be possible to index the talent characteristics according to their relative stability (Havlicek et al., 1982). This system would involve assigning a weighting to each talent characteristic on the basis of their relative stability and their resistance to change in response to a training stimulus. Through such a system it may be possible to determine whether a gymnast possesses the critical antecedents necessary to achieve success and to evaluate her profile in order to estimate how difficult it will be to maintain the gymnast's strengths and realise her weaknesses. If the profile indicates numerous weaknesses all of which are difficult to correct, the limited career span may preclude the attainment of high level performances. Moreover, the realisation of such a profile may require a particularly demanding training programme which the gymnast may not enjoy or be motivated to

follow. It is anticipated that through a systematic evaluation of the profile, the most appropriate level for the gymnast to participate may be identified to maximise the gymnast's potential to achieve future success and to derive a pleasurable experience of gymnastics.

As previously highlighted, additional talent characteristics which are sensitive to the growth and maturation of the child should also be monitored throughout the development programme. Changes in these characteristics have implications for the acquisition and maintenance of gymnastic skills and the development of talent characteristics. It is anticipated that through a more complete understanding of the development of these characteristics coaches may structure the training process more effectively and may become increasingly aware of changes in the talent characteristics and the physical and psychological consequences of these changes. To address these issues and progress towards a more sophisticated system of talent identification and development will require a more comprehensive longitudinal investigation of the nature and rate of development of talent characteristics in relation to the training stimulus. It is strongly recommended that as understanding of the talent process is enhanced through research, an additional programme of coach education is introduced to support the National system of talent identification focusing specifically upon the issues pertinent to talent development within the young female gymnast.

Future directions

The present study was associated with several limitations which may be addressed through future research to provide a more complete understanding of the talent process. Firstly, the present study was exploratory in nature and sought to identify a small number of prognostic talent components which may be considered suitable for inclusion into a National system of talent identification and development. As a result of the large number of talent characteristics assessed, the size of both 'pooled' and 'gymnasts only' samples were relatively small which limited the statistical analyses which could be applied. Future research will be necessary to determine whether the relationships identified within the present study can be confirmed within larger samples of gymnasts and controls.

Moreover, it is anticipated that the use of a larger, more representative pooled sample will reduce the non-normality and in particular the skewness of the data which resulted in the omission of a number of potentially prognostic talent characteristics within the present investigation. Finally, access to large samples of gymnasts and controls through a National system of talent identification and development would permit the employment of sophisticated statistical analyses through which the longitudinal development of talent characteristics may be modelled. A larger sample size would also permit a more detailed examination of the nature and the direction of the relationships between talent characteristics and between talent characteristics and future gymnastic performance.

Talent characteristics are recommended for inclusion in the initial identification battery based upon their longitudinal stability and the accuracy with which they distinguished between gymnasts and controls. However, at the time the initial characteristics were measured the gymnasts had been training for approximately 4.5 years. Therefore, it was not possible to conclusively state whether the differences in talent characteristics observed between gymnasts and controls were primarily due to innate factors or whether they emerged as a result of the long term effects of training. This question may only be addressed by conducting longitudinal research in conjunction with a National system of talent identification in which the initial talent characteristics are measured within a large sample of children and their development monitored throughout the career span.

Although an inclusive approach was adopted within the present investigation, it is acknowledged that additional characteristics which were not included in the current test battery may play an important role in the identification and development of gymnastic talent. Moreover, several intuitively important talent characteristics could not be reliably measured within the present study, with poor measurement reliability being of greatest concern within the perceptual-motor dimension of performance. As a result of these limitations, it is recommended that the National system and associated research programme is dynamic in nature with scope to include additional measurements and refinements to the measurement procedure. It is also important to emphasise that the inability of a characteristic to distinguish between groups within the 'gymnasts only' sample does not necessarily indicate the unimportance of this characteristic and may instead reflect the ability of both successful and unsuccessful gymnasts to train this talent

characteristic effectively. It is therefore important that when the results of the present study are used to inform the structure and organisation of training such characteristics are not neglected.

Regular medical assessments were considered to be an essential component of international systems designed to identify and develop gymnastic talent (Karacsony, 1988; Fisher & Borms, 1990; Mashi & Xhang, 1995). It is therefore suggested that a further avenue for future research concerns the development of a comprehensive system of medical monitoring. It is recommended that medical assessments are introduced at an early stage of the talent process to ascertain the child's suitability for future intensive training and to detect specific aspects of posture, skeletal alignment and/or muscular imbalance which may require specific attention from a young age. It is also recommended that a comprehensive programme of medical screening provides additional information regarding the identification of anatomical constraints which may restrict the development of physical talent characteristics. For example, it may be possible to determine whether the shape of the bony articulating surfaces may limit range of motion in the hip, shoulder or pelvic regions in certain individuals.

On the basis of the present research it is recommended that a National system of talent identification and development should be introduced into the regional structure of British Gymnastics. However, prior to the establishment of such a system a pilot study will be necessary to determine whether the selected talent characteristics may be assessed reliably and safely in primary school children as young as five to six years of age. The present research has established the nature of relationships between talent characteristics and future gymnastic performance. However, it will only be appropriate to use logistic regression models which have been derived from longitudinal data collected through an applied research programme. It is recommended that until such information is available normative data is obtained regarding the talent characteristics of five to six year old children and identification is based upon these data in accordance with the relationships reported in the present investigation. A further important function of the pilot study will be to determine time and resource requirements associated with conducting the initial identification battery. It will also be beneficial during the pilot scheme to examine the partnership options which may be established between the schools and the coaches

responsible for conducting the initial identification assessments. It is strongly recommended that coaches perform a dual role whereby they assist teachers with physical education classes in addition to identifying talented children (Stan, 1995). Details regarding this relationship are yet to be established, however, it is recommended the model is sufficiently flexible to accommodate local differences.

The philosophy upon which the National system is based will be a key determinant of the future success of the identification and development programme. It will be important that the system of identification functions to provide opportunities for those children who demonstrate a talent for Women's Artistic Gymnastics. In line with the guidance approach advocated by Bompa (1985), the system must be viewed as part of a wider development programme through which children who wish to commence gymnastics may be guided to participate at a level which is commensurate with their ability. With respect to the development of talent once identified, it will be critical that the pathway or programme of talent development is integrated into the existing system and has the full support of the coaching community. This infrastructure will be important to support those children who consistently fail to reach the required performance standards and those who choose not to remain within the programme but wish to continue participating in the sport. Moreover, an appropriate supporting structure will provide sufficient flexibility to permit children to move between 'elite' and 'club' based development programmes. It is recognised that the recommended integration of elite and club-based systems will be difficult for coaches and gymnasts and will require careful management particularly at the points of transition between systems. It will be essential for the integrated system of talent identification and development to be managed within a culture of teamwork and cooperation with each member of the team encouraged to feel valued and aware of their contribution to the overall development programme. This may be facilitated by establishing an appropriate reward structure which recognises the team effort and the contributions of coaches at all levels of the development process.

Summary

Several key issues were raised in the review of previous research which demand consideration in the systematic identification and development of talent. The results of the present study revealed that the female gymnast has a clearly defined physical profile and that several components of this profile may be identified within children from a young age. For the majority of physical tests biological maturity does not appear to have a major influence upon the physical performance of young females (Beunen & Malina 1996; Malina, 1996a; Beunen et al., 1997b; Little et al., 1997). Therefore, with the possible exception of static strength, it is not necessary to index talent characteristics according to the maturity status of the child. Issues were also raised regarding the influence of previous motor experience upon performance at the initial stage of identification. However, the age at which children are identified to participate in gymnastics ensures that the previous motor experience of children will have only a minor effect upon their performances during the initial identification of talent. Finally, the incorporation of an element of forward thinking was considered to be an essential aspect of the talent process (Régnier et al. 1993). Prognosis may be considered particularly relevant in gymnastics given the amendments to the Code of Points which are introduced at the end of each Olympic cycle. However, the effect of these changes are anticipated to be most evident in the later stages of talent development with little impact upon initial identification and the early stages of talent development programmes (Linderholm & Simon, 1988; Smolevski, 1992; Stan, 1995). It may therefore be concluded that the nature of the sport and the profile of the elite female gymnast ensure that, in light of the key issues considered, talent identification is an appropriate pursuit within Women's Artistic Gymnastics.

The present study examined the relationship between talent characteristics and future gymnastic performance and highlighted a number of characteristics which have a potentially prognostic role in the initial identification and subsequent development of talent in young female gymnasts. On the basis of the present research it is recommended that a National system of talent identification and development is introduced into the regional structure of British Gymnastics. This system will complement the existing initiatives introduced through the World Class Programme thereby providing a continuous pathway from the initial identification of talent through to the achievement of excellence (Prescott,

1999, unpublished). The present study has provided the initial framework through which to establish a coordinated approach combining both research and practical application. Through such an approach the practical aim of performance prediction may be integrated within a comprehensive programme of research. It is anticipated that as the inherent complexity of the talent process becomes more clearly understood through research more accurate predictions of the future performance of young female gymnasts may be derived. It is expected that support for such a system would be favourable within the coaching community with 80% of the coaches in the present study indicating that they would welcome the publication of National guidelines on the subject of talent identification and development.

In line with the suggestions for future research, it is recommended that studies are conducted to investigate the nature of relationships between talent characteristics while continuing to adopt an holistic approach to the identification and development of talent. It is important that the pursuit of future research is accompanied by a recognition that talent identification cannot be viewed as a precise science nor conceptualised as a problem which may be solved by deriving a single, unique solution. Progress in this area will only be achieved through the continued efforts of a dedicated research team striving to build a more complete picture of this complex area.

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APPENDIX 3

APPENDIX 3.1: Ethical submission and approval (R97/26)

APPENDIX 3.2: Medical history questionnaire
Informed consent form
Information for subjects

APPENDIX 3.3: Assessment charts for technical skill acquisition

APPENDIX 3.4: Rules and requirements for IGA competition (modified code)

APPENDIX 3.5: Performance scores

Appendix 3.1

LOUGHBOROUGH UNIVERSITY OF TECHNOLOGY

ETHICAL ADVISORY COMMITTEE

RESEARCH PROPOSAL FOR HUMAN BIOLOGICAL INVESTIGATIONS

This application should be completed after reading the Code of Practice paying particular attention to the advice given in Section 6.3.

(i) Applicants

Joanna Prescott BSc, MSc, Department of Physical Education, Sports Science and Recreation Management. Supervised by Mr D.G.Kerwin, Director of Studies, Sports Science. Director of Research Professor C. Williams.

(ii) Project Title

Identification and Development of Talent in Young Female Gymnasts.

(iii) Aims and of the Project:

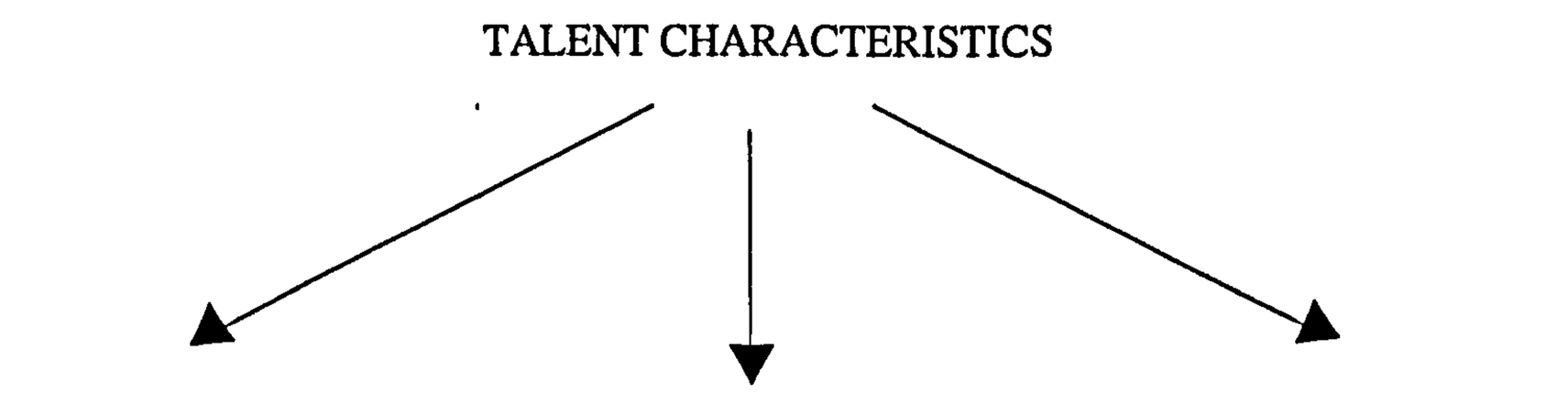
The research seeks to determine whether it is possible to identify a set of talent characteristics that would enable the prediction of future performance in young female gymnasts. The research aims to establish the merits of talent identification, talent development (training) and the respective interaction effects. It is anticipated that the study will provide an insight into the longitudinal development of the chosen talent characteristics and highlight methodological implications relating to the structure of training. The project has the full backing of the British Amateur Gymnastics Association (B.A.G.A.).

(iii) Outline of the Project

The practical study is longitudinal in nature with a mixed series approach. The initial talent characteristics of 72, 8-10 year old female gymnasts will be assessed using a battery of tests designed to measure various physical, perceptual and psychological characteristics (Figure 1).

At the end of a 12 month period of study the performance of the gymnasts will be evaluated in terms of their competitive performance and technical skill acquisition. A causal modelling technique will be applied retrospectively to evaluate models of performance in terms of which of the initial talent characteristics best predicted the final performance.

Repeated measurements of the talent characteristics will be taken every six months to provide an insight into the development of the chosen talent characteristics and in particular the relationships that exist between those characteristics as the child grows and matures. It is envisaged that the longitudinal nature of the study will assist the identification of the most receptive stages for the development of the talent characteristics.



PHYSICAL	PERCEPTUAL	PSYCHOLOGICAL
anthropometry	kinesthesis	intrinsic motivation
inertia	balance	perceived competence
force	postural sway	goal orientation
force-velocity		competitiveness
flexibility		motivational climate

Figure 1. Illustration of talent characteristics.

(iv) Names and Status of Investigators:

Joanna Prescott BSc, MSc, Research Student, Department of Physical Education, Sports Science and Recreation Management. Supervised by Mr D.G.Kerwin. Director of Research Professor C. Williams.

Adrian Stan - National coach for women's artistic gymnastics to assist in conducting the technical skill assessments with Joanna Prescott.

Psychological inventories to be administered in consultation with Dr A.B. Swain and Dr J.G. Jones

Assessment of skeletal maturation to be conducted by Dr M.J.Aldridge consultant orthopaedic surgeon at Coventry & Warickshire Hospital. BOA scientific / medical committee.

Postural assessment to be supervised by Lizzie Lane, Chartered Physiotherapist

(v) Subjects (see section 6.3e):

72 female gymnasts will be recruited from major gymnastics clubs in England. All clubs involved are registered with the B.A.G.A. and all coaches hold appropriate B.A.G.A. coaching qualifications. Recruitment will be via a letter of invitation to head coaches to participate in the study supported by the Technical Director and President of the B.A.G.A. A lay summary of the study design was sent out with the letter of invitation to participate. Parental consent forms and medical history questionnaires will be sent to all the parents of all participants named as potential subjects by the coaches.

(vi) Location (any special facilities to be used):

The test battery will be completed in the Sports Biomechanics Laboratory (UU 0.12) in the Department of Physical Education, Sports Science and Recreation Management at Loughborough University. The technical skill acquisition will be conducted in the gymnast's club. The competitive venue is to be decided by the Women's Technical Committee of the B.A.G.A. All radiographs/medical assessments will be taken at the Warwickshire Orthopaedic Hospital (St Gerard's).

(vii) Duration (including demand on subject's time):

The practical aspect of the study is for a duration of 12 months. Technical skill will be assessed twice and will take approximately 4 hours on each occasion. Each of three measurement sessions will last for 4 hours. The radiographs and medical assessment will be completed within a single one hour session. The competition, part of the annual gymnastic calendar in which the majority of participants will compete regardless of their participation in the study, will take approximately 5 hours. Total time demanded of subjects over the 12 month study period = 26 hours

(viii) Reasons for undertaking the study (eg contract, student research):

This is a student research study which has the full support of the British Amateur Gymnastic Association.

(Ix) Methodology (a brief outline of research design):

The initial performance of the gymnasts at the outset of the study will be assessed via the age related technical skill charts devised by the Women's National Coach. The first administration of the test battery will take place at Loughborough University on the weekend of 13-16th September. The test battery described below will be administered to the sample of 72 gymnasts, with the weekend divided into six 4 hour measurement sessions with 12 gymnasts attending each measurement session. The same battery of tests will be repeated in 6 and 12 months time. The final performance of the gymnasts will be assessed in September 1997 and will consist of an assessment of technical skill acquisition and the gymnasts competitive performance in the B.A.G.A. Age Group championships.

Performance attributes will be determined prior to the commencement of the study via the technique of performance profiling. During the administration of the test battery, the personal coaches of the gymnasts will be asked to rate the current level of ability of their gymnasts on the agreed attributes.

Information regarding the competitive performance, training status, and any injuries sustained during training will be collected from coaches during the course of the study. In addition, in the event of attrition from the sport the gymnast, her parents and coach will be required to state their perceptions of the reasons for the retirement.

Attempts are being made to arrange a postural screening. If successful, this will be completed by a chartered physiotherapist who has experience working with National gymnastics squads. It is proposed that the assessment will take place in conjunction with a single A-P radiograph of the gymnast's left hand to enable bone age to be calculated. All radiographs will be taken at The Warwickshire Orthopaedic Hospital (St Gerard's), Coleshill, Warickshire.

(x) Procedures and measurements (for experimental and control subjects):

The test battery comprises 4 stations, each station lasts for a duration of 60 minutes with three gymnasts at each station. The test battery is made up of the following components:

STATION 1

anthropometric measurements; height, weight, sitting height, skeletal lengths, breadths, armspan and range of shoulder extension. Body fat measurements at four sites; biceps, triceps, subscapular and iliac crest.

inertia measurements; a series of 95 anthropometric measurements (34 lengths, 41 perimeters, 17 widths and 3 depths) required to estimate the inertia parameters according to the model of Yeadon (1990).

STATION 2

Isometric strength; an isometric strength testing rig mounted on a Kistler force plate will be used to assess force production and rate of force production for the following joint actions; shoulder flexion and extension, shoulder girdle elevation and abduction, hip flexion and extension, knee extension, ankle plantar flexion and trunk flexion and extension.

In addition, the gymnastic specific dynamic strength tests performed over 60 seconds devised by the Women's National Coach will be assessed in the gymnast's club situation.

vertical jumps; 3 maximal effort counter-movement jumps and 3 maximal effort drop jumps from a drop height of 15 cm will be performed on a Kistler force plate flush with a continuous runway.

Postural sway; A single 30s trial in each of the following conditions will be performed on a Kistler force plate: two feet eyes closed, one foot eyes open and one foot eyes closed.

STATION 3

Flexibility; After a standardised 4 minute warm-up, a MIE inclinometer will be used to estimate the range of motion of the following joint actions; shoulder flexion and extension, internal/ external rotation of the shoulder girdle, elbow hyper-extension, wrist flexion and extension, hip flexion and extension, hip external rotation, hip abduction, knee hyper-extension, flexion and extension of the lumbar and thoracic spine.

In addition a series of static and dynamic gymnastic flexibility measurements will be video recorded and subsequently digitized using the TARGET system. A two dimensional Direct Linear Transformation will be applied to enable the joint angles to be calculated from the video data.

STATION 4

Balance; a modified version of the Nelson balance test (Johnson & Nelson, 1986) which comprises static and dynamic balance elements

Kinesthesis

i) Matching; Each gymnasts will be shown a photograph of a young gymnast in a seated position with her knee at a specific angle of flexion and asked to match this angle with her own leg, with vision of the leg occluded. Once the gymnast has indicated that their best effort at reproducing this angle been achieved a still photograph will be taken. This angle will be subsequently determined and compared to the reference photograph.

ii) Pointing: Each gymnast will be seated and asked to look at the position of a bar suspended in space. Upon completing a 180° turn so the bar is now out of sight the gymnast will stand and point to the position in space she perceived the bar to be located. The gymnast's perception of the bar's location will be recorded from a scale visible only to the observer.

iii) Perception of force; Each gymnast will perform a maximal broad jump on gymnastic mats, the distance of the jump will be recorded. Half this distance will be marked and shown to the gymnast. The gymnast will then move forward to the next set of mats and is asked to jump this new distance (ie exactly half the distance of the first jump). Three attempts are given and the best score recorded.

iv) Perception of timing; A single segment computer simulation model of a gymnast performing a giant circle has been developed (Hiley, 1996). The model requires the gymnast to click the mouse button of the computer when she perceives the bottom of the giant circle is reached (i.e. the model has completed 180° of rotation about the bar). The model outputs a score in degrees to indicate the deviation from the desired angle. 10 attempts are given and the average of all trials is taken.

v) Perception of rotation; The gymnast is asked to stand on a 1m x 1m board with the midline between the feet running along a thin black line marked down the centre of the board. The gymnast is then asked to complete a 360° turn with the eyes closed a finish in an upright standing position. The recorder then asks the gymnast to move one foot and places a 300mm steel ruler adjacent to the medial side of the stationary foot. The angle between the steel ruler and the midline marked on the board is recorded in degrees using a protractor. 5 attempts are given and the average deviation in degrees is taken as the score.

Psychological inventories; Modified (gymnastic specific) versions of the following inventories will be administered, with 1/2 inventories allocated to each station.

Task and Ego Orientation in Sport Questionnaire (TEOSQ) (Duda & Nicholls, 1991), competitiveness scale of the Sport Orientation Scale (SOQ) (Gill & Deeter, 1988), Motivational Orientation in Sport scale (Intrinsic/Extrinsic Sport Motivation Scale) (Weiss, Bredemeir & Shewchuk, 1985), Harter's (1985) physical scale for perceived competence, perceived motivational climate in sport questionnaire & two measures of sport enjoyment (Scanlan, Simons, Carpenter, Schmidt & Keeler, 1993).

(xi) Possible risks, discomforts and/or distress (see Section 6.3k):

The risk to subjects during the measurement of the characteristics included in the test battery and the assessment of technical skill acquisition are minimal and consequent with the risk involved in their normal gymnastic training. The risk during the competitive performance will be identical to that of any gymnastic competition.

(xii) Procedures for taking measurements and for chaperoning and supervision of subjects during investigations:

At all measurement and assessment sessions a coach from the gymnast's club is required to attend for the purposes of transport and chaperoning. In addition to the named investigator there will be two full-time research students and a laboratory technician to take measurements and supervise at each testing station. Undergraduate students will be recruited to assist these personnel to ensure that there are a minimum of two persons to each station. In addition one person will be 'free' to assist as required with any other matters. For all assessments, with the exception of anthropometric measurements, the gymnasts will be required to wear sleveless leotards (normal training attire). For the anthropometric measurements a bikini or crop top is requested. These measurements will be taken in a private area of the laboratory, separated from the main testing area. These measurements will be taken by a female measurer (Joanna Prescott) in the presence of a recorder.

(xiii) Names of investigators and personal experience of proposed procedures and/or methodologies:

Anthropometric/inertia measurements: J.Prescott trained by Professor Peter Jones, Department of Human sciences.

Isometric Strength / vertical jump / postural sway: L. Griffin Sports Biomechanics Laboratory Technician, Department of Physical Education, Sports Science and Recreation Management Department. Lesley has extensive experience in using the Kistler force plate with undergraduate and postgraduate Laboratory classes.

Functional strength (gymnastic measurements): - J.Prescott & Adrian Stan (National Coach Women's Artistic Gymnastics).

Flexibility measurements: Goniometer measurements will be taken by Michael Hiley and Mark Brewin (year 3 and year 2 PhD students in Sports Biomechanics respectively).

Kinesthesis / balance measurements: will be taken by Simon Browne BSc (Sports Science).

Psychological inventories: to be administered by undergraduate students within the Department of Physical Education, Sports Science and Recreation Management under the supervision/guidance of Dr J.G. Jones / Dr A. Swain.

Radiographs: will be taken by Dr M.J.Aldridge Consultant Orthopaedic Surgeon and team doctor for the British Amateur Gymnastics Association.

Postural assessments: will be taken by Lizzie Lane Chartered Physiotherapist, Lizzie has experience working with women's National gymnastics Squads at numerous major International events

(xiv) Details of any payments to be made to the subjects:

Petrol money will be offered to cover transport costs to and from assessment sessions.

(xv) Do any investigators stand to gain from a particular conclusion of the research project:

No

(xvi) Whether the University's Insurers have indicated that they are content for the University's Public Liability Policy to apply to the proposed Investigation (Committee use only):

(xvii) Whether insurance cover additional to (xv) has been arranged by the Investigator (see Section 6.3o):

All gymnasts involved in the study are associate members of the B.A.G.A and are hence insured for the purposes of gymnastic training and competition under the B.A.G.A. insurance scheme.

(xviii) In the case of studies involving new drugs or radioisotopes, written approval for the study must be obtained from the appropriate national body and submitted with the protocol. State if applicable:

Not applicable.

(xix) Declaration

I have read the University's Code of Practice on Investigations on Human Subject's and completed this application.

Signature of applicant: .....

Signature of Head of Department: .....

Date .....

Ref No: R 97/26

LOUGHBOROUGH UNIVERSITY
ETHICAL ADVISORY COMMITTEE

HUMAN BIOLOGICAL INVESTIGATION
RESEARCH PROPOSAL

Title: Identification and development of talent in young female gymnasts

Applicants: Dr D Kerwin, J Prescott & Prof C Williams

Department: Physical Education, Sports Science and Recreation Management

Date of Clearance: 25 September 1997

Comments of the Committee: The Committee was content to issue clearance after receiving a satisfactory response to their comments

Investigators: Dr David Kerwin, PE, SS & RM

Jo Prescott, PE, SS & RM

Prof C Williams, PE, SS & RM

PARENTAL PRE-SELECTION MEDICAL QUESTIONNAIRE
LOUGHBOROUGH UNIVERSITY
DEPARTMENT OF PHYSICAL EDUCATION, SPORTS SCIENCE AND RECREATION MANAGEMENT

Please read through this questionnaire, BUT DO NOT ANSWER ANY OF THE QUESTIONS YET. When you have read right through there may be questions you would prefer not to answer. In this case please tick the box labelled "I wish to withdraw my daughter" Immediately below. Also tick the box labelled "I wish to withdraw my daughter" if there is any other reason for her not to take part.

	tick appropriate box
I wish to withdraw my daughter	☐
I am happy to answer the questionnaire	☐

If you are happy to answer the questions posed below on behalf of your daughter, please proceed. Your answers will be treated in the strictest confidence.

1. Is your daughter at present recovering from any illness or operation? YES/NO*

2. is your daughter suffering from or has she suffered from or received medical treatment for any of the following conditions?

a.	Heart or circulation condition?	YES/NO*
b.	High Blood pressure	YES/NO*
c.	any orthopaedic problems	YES/NO*
d.	any muscular problems	YES/NO*
e.	Asthma or bronchial complaints	YES/NO*

3. Is your daughter currently taking any medication that may affect her participation in the study YES/NO*

4. Is your daughter recovering from any injury? YES/NO*

5. Is your daughter epileptic YES/NO*

6. Is your daughter diabetic YES/NO*

7. Are you aware of any other condition or complaint that may be affected by participation in this study. If so, please state below; YES/NO*

.....

.....

.....

.....

* Delete as appropriate

PARENTAL CONSENT FORM

LOUGHBOROUGH UNIVERSITY
DEPARTMENT OF PHYSICAL EDUCATION, SPORTS SCIENCE AND RECREATION MANAGEMENT

1. I,.....
consent to my daughter (insert full name of child)
.....
taking part in the study to identify gymnastic aptitude at Loughborough University, Department of Physical Education, Sports Science and Recreation Management. An explanation of the nature and purpose of the study has been given to me and I understand that my daughter may withdraw from the study and that I am under no obligation to give reasons for withdrawal.

2. My replies to all the questions above are correct to the best of my knowledge and belief.

3. I understand that the information about my daughter given by myself will be treated as confidential by the experimenters.

4. The experimenter has provided a satisfactory explanation of the nature and purpose of the study, the nature of the testing and the possible risks involved.

5. While agreeing to attend for the purpose of the study I fully understand that my daughter may withdraw from taking part in the study, and that I am under no obligation to give any reason for my daughter's withdrawal, or for her to to attend any further measurement sessions.

6. While in the biomechanics laboratory or any associated laboratory or medical facility, I undertake that my daughter will obey any regulations in force governing its use, and the instructions given to her by the experimenter(s) regarding safety and study procedures, subject only to my daughter's right to withdraw as declared above.

Date .....

Parental Signature .....

Signature of Director of
Research/Supervisor .....

I. G. A.
Identification of Gymnastic Aptitude

INFORMATION FOR PARENTS

This study in which your daughter is invited to participate aims to establish whether it is possible to identify talent in the young female gymnast. More specifically, the study seeks to determine whether by measuring certain characteristics in the young gymnast it is possible to predict her future performance. The research also seeks to gain an insight into the way these characteristics develop as children grow and mature and the implications this development may have for the way gymnastic training is structured. This study is strongly supported by the British Amateur Gymnastics Association.

Your daughter, accompanied by her coach, will be required to attend Loughborough University once every 6 months to complete a battery of tests designed to identify talent (September 1996, March 1997, September 1997). These tests are considered to be of minimal risk, equal to the level of risk during a standard club training session. The testing will include anthropometric, strength, flexibility and power measurements. Assessments will be taken of each gymnast's ability to balance, to determine the position of her body in space and to assess her perception of force, timing and rotation. In addition, each gymnast will be required to complete several questionnaires designed to assess certain psychological attributes such as competitiveness and motivation.

The information obtained at these measurement sessions will be collected and stored in adherence with the Data Protection Act. Whilst certain personal and training information will be required from gymnasts, their parents and coaches, all gymnasts will be allocated a reference number to protect their anonymity. The identity of gymnasts will remain confidential in any material resulting from this work.

The study will include a brief medical examination supervised by a chartered physiotherapist and an x-ray of the left wrist. This x-ray is necessary to determine the gymnast's bone age or the maturity of her skeleton. These will be conducted at an orthopaedic hospital in the West Midlands by Dr John Aldridge, Consultant Orthopaedic Surgeon, Consultant of the B.A.G.A. Medical insurance scheme.

The Performance of the gymnasts will be assessed at the beginning and end of the study period. At the beginning of the study an assessment of which gymnastic skills the gymnast is able to perform will be made. This will be conducted in the club by the Women's National coach, Adrian Stan. At the end of the study the all gymnasts will be required to repeat this technical skill assessment and to participate in a competition to assess their performance.

Talent Identification & Development - Lay summary of Research Design

The study seeks to determine whether it is possible to identify a series of talent characteristics that would enable the prediction of future performance in Women's Artistic Gymnastics. The initial talent characteristics will be measured at the commencement of the study together with an assessment of the initial skill level of the gymnasts. After a 12 month period of training, performance will be re-assessed. Statistical modelling techniques will then be applied retrospectively to determine which of the initial talent characteristics were the best predictors of the future performance of these gymnasts. The same battery of tests will be applied every 6 months to provide information regarding how talent characteristics develop during the course of the study period. A total of 72 female gymnasts aged 8-10 years will be selected to participate in the study. These gymnasts will be recruited from the major gymnastics clubs in the country. Gymnasts with birth dates between 01/07/86 - 30/06/88 who are currently involved in artistic gymnastics and able to complete in the Age Group Championships in October 1997 will be invited to participate. Full written consent will be required from the parents of those gymnasts involved.

The gymnasts will be required to attend Loughborough University once every 6 months to complete a battery of tests designed to identify talent (September 1996, March 1997, September 1997). The testing will be conducted at weekends or during school holidays. The coach who most frequently works with the gymnast will be required to attend the testing sessions which are anticipated to last for 4 hours. Measurements will be taken in the physical, perceptual-motor and psychological dimensions of performance, more specifically, the test battery will include an assessment of the following characteristics: Physical (anthropometry, strength, speed-strength, flexibility, inertia) Perceptual-motor (kinesthesis, balance, postural sway) Psychological (intrinsic motivation, goal orientation, motivational climate, perceived competence competitiveness and sport enjoyment).

Radiographs of the left wrist of the gymnasts will be taken for the determination bone age by Dr John Aldridge Consultant Orthopaedic Surgeon and Member of Scientific Commission at the Warwickshire orthopaedic Hospital, Coleshill, Birmingham. Postural examinations will be conducted at the hospital by a chartered physiotherapist with experience working with Women's National Gymnastic Squads. In addition, the coaches working most closely with the gymnasts will be asked to subjectively rate their gymnasts on a series of talent characteristics suggested to be the necessary attributes of an 'ideal' young female gymnast. The senior coaches from each club will be asked to periodically provide information regarding the training status of their gymnasts, the results of any competitive performances and any injuries or drop-outs that may occur during the course of the study.

Performance will be assessed at the beginning and end of the study period. The assessment at the beginning of the study will comprise a technical skill assessment conducted in the gymnast's club according to the projected charts devised by Adrian Stan. At the end of the study all gymnasts will be required to repeat this technical skill assessment and to participate in a competition to assess their performance. The coaches will also be required to attend these assessment sessions.

Appendix 3.3

VAULT	0	1	2	3	4	5	6
Handspring							
Handspring1/1							
Handspring front (tucked)							
Handspring front (piked)							
Tsukahara tucked							
Tsukahara piked							
Tsukahara stretched							
Yurchenco tucked							
yurchenco piked							
yurchenco stretched							

BARS	0	1	2	3	4	5	6
Upstart cast to handstand x3							
Forward swing in hang - overgrasp							
Backward swing in hang overgrasp							
Cast to handstand - overgrasp							
Cast to handstand - undergrasp							
Cast to handstand with 1/2 turn							
From h/stand b/ward downswing							
From h/stand forward down swing							
Short clear circle to handstand x3							
Front giant x3							
Back giant x3							
Back giant to backaway							
Front giant to front away							
Dismount D or E (C=-1: B=-2)							
Element to handstand with 360 degrees							
First Release & Catch							
Release & Catch E or second R & C							

Appendix 3.3

BEAM	0	1	2	3	4	5	6
Sissone							
Split leap forward							
Side straddle jump in cross position							
Change leg split leap							
1/1 turn passe/develope							
Cartwheel							
Round-off							
Forward walkover							
Backward walkover							
Backflip split legs (1,2 or 3)							
Backflip (1,2 or 3)							
Tucked somersault (backwards)							
Piked back somersault							
straight back somersault							
R/o straight dismount							
R/o 2/b dismount or more than 2/1							
Free cartwheel/walkover							
first element/combination with bonus							
second element/combination with bonus							
Series ACRO GYM (value & execution)							
Series GYM GYM (value & execution)							

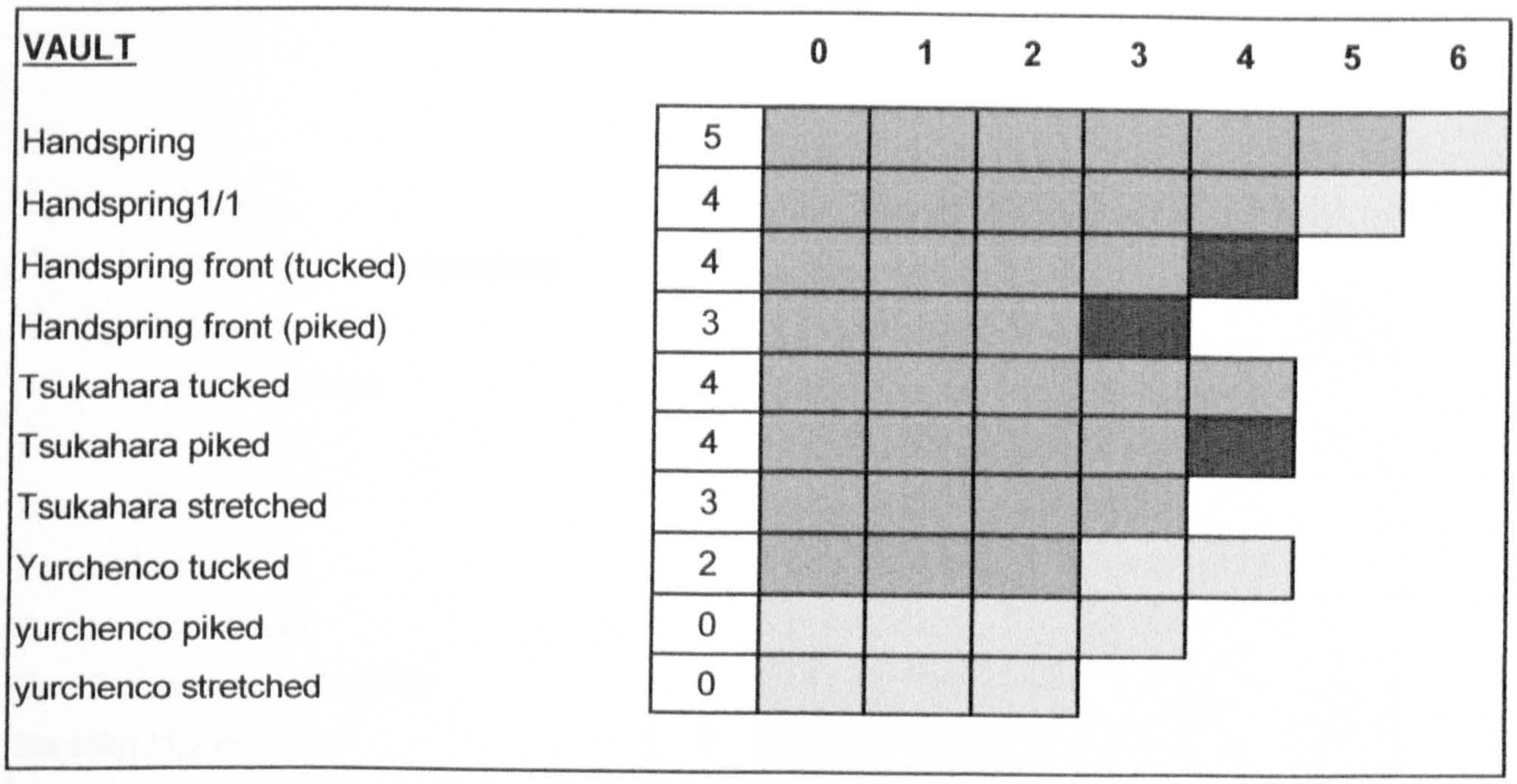
Appendix 3.3

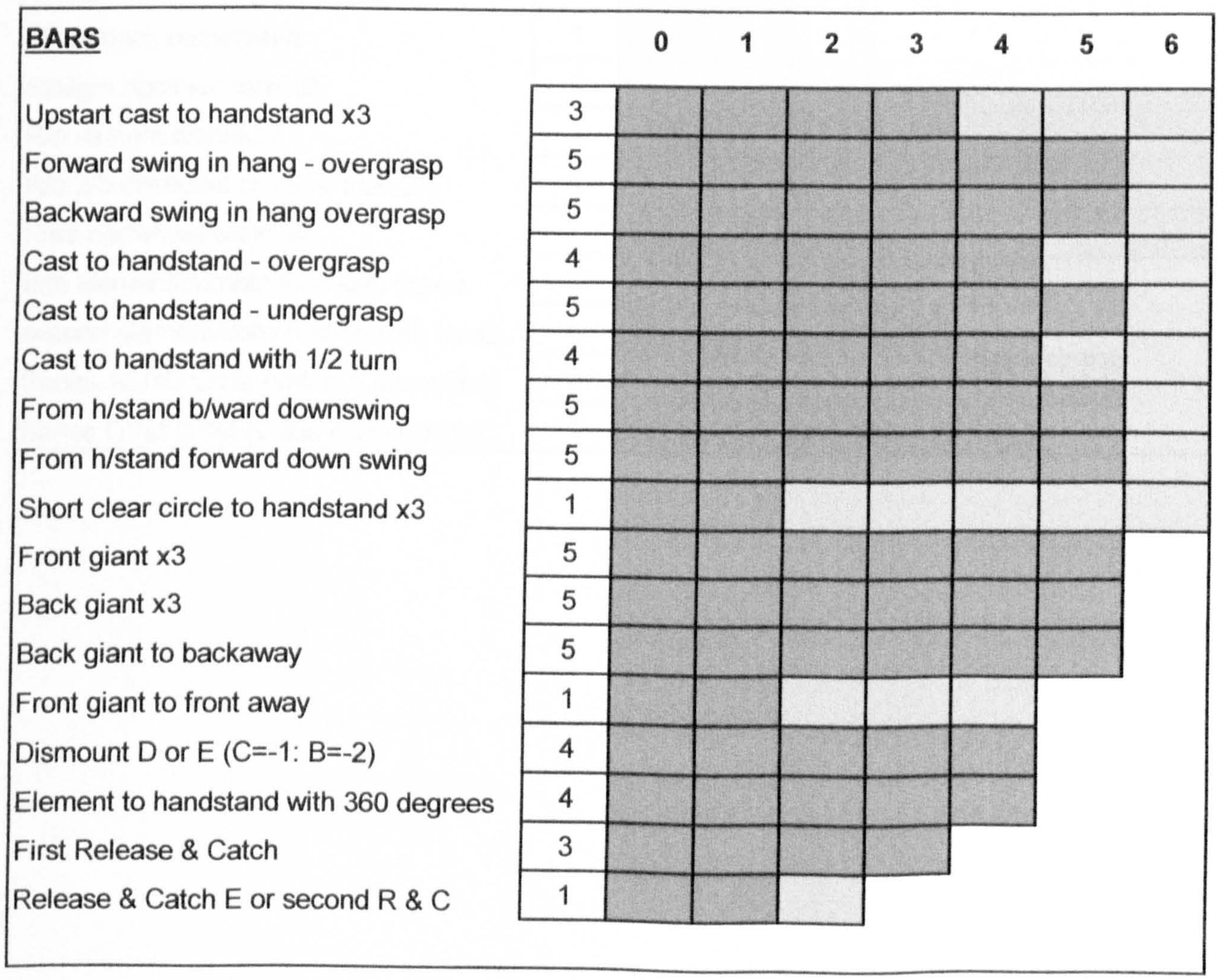
FLOOR	0	1	2	3	4	5	6
Forward roll							
Backward roll							
Backward roll to handstand							
Cartwheel -sideways							
Round-off							
Free cartwheel							
Free walkover							
Headspring							
Forward walkover							
Back walkover							
Handspring - one leg							
Handspring - two legs							
Flyspring							
Backflip split legs							
Backflip two legs							
Dive forward roll							
Back somersault - tucked							
Back somersault - stretched							
Back somersault 1/1 turn							
Back somersault 2/1 turn							
Double back -tucked /piked							
Full in back out							
Front somersault step out							
Arabian - tucked/piked/straight							
Whip back							
first element/combination with bonus							
second element/combination with bonus							
Series ACRO GYM (value & execution)							
Series GYM GYM (value & execution)							

Appendix 3.3

CHOREOGRAPHY	0	1	2	3	4	5	6
Sissone							
Split leap forward							
Split leap forward 1/4 turn							
Split leap change leg							
Scissors leap forward 1/2 turn							
1/1 turn passe to develope							
2/1 spin							
Jump with 1/1 turn							
Jump with 2/1 turn							
Straddle pike jump							
Straddle jump							
Hop with 1/2 turn one leg extended							
Side split							
Cross split - right							
Cross split - left							

Appendix 3.3


VAULT
0 1 2 3 4 5 6
Handspring 5
Handspring1/1 4
Handspring front (tucked) 4
Handspring front (piked) 3
Tsukahara tucked 4
Tsukahara piked 4
Tsukahara stretched 3
Yurchenco tucked 2
yurchenco piked 0
yurchenco stretched 0


BARS
0 1 2 3 4 5 6
Upstart cast to handstand x3 3
Forward swing in hang - overgrasp 5
Backward swing in hang overgrasp 5
Cast to handstand - overgrasp 4
Cast to handstand - undergrasp 5
Cast to handstand with 1/2 turn 4
From h/stand b/ward downswing 5
From h/stand forward down swing 5
Short clear circle to handstand x3 1
Front giant x3 5
Back giant x3 5
Back giant to backaway 5
Front giant to front away 1
Dismount D or E (C=-1: B=-2) 4
Element to handstand with 360 degrees 4
First Release & Catch 3
Release & Catch E or second R & C 1

Appendix 3.3

BEAM		0	1	2	3	4	5	6
Sissone	4							
Split leap forward	4							
Side straddle jump in cross position	4							
Change leg split leap	5							
1/1 turn passe/develope	6							
Cartwheel	5							
Round-off	4							
Forward walkover	4							
Backward walkover	4							
Backflip split legs (1,2 or 3)	5							
Backflip (1,2 or 3)	5							
Tucked somersault (backwards)	1							
Piked back somersault	1							
straight back somersault	4							
R/o straight dismount	4							
R/o 2/b dismount or more than 2/1	4							
Free cartwheel/walkover	1							
first element/combination with bonus	4							
second element/combination with bonus	3							
Series ACRO GYM (value & execution)	5							
Series GYM GYM (value & execution)	4							

Appendix 3.3

FLOOR		0	1	2	3	4	5	6
Forward roll	6							
Backward roll	6							
Backward roll to handstand	6							
Cartwheel -sideways	6							
Round-off	6							
Free cartwheel	5							
Free walkover	4							
Headspring	5							
Forward walkover	6							
Back walkover	5							
Handspring - one leg	5							
Handspring - two legs	5							
Flyspring	5							
Backflip split legs	6							
Backflip two legs	5							
Dive forward roll	5							
Back somersault - tucked	6							
Back somersault - stretched	5							
Back somersault 1/1 turn	6							
Back somersault 2/1 turn	6							
Double back -tucked /piked	5							
Full in back out	3							
Front somersault step out	6							
Arabian - tucked/piked/straight	3							
Whip back	5							
first element/combination with bonus	5							
second element/combination with bonus	3							
Series ACRO GYM (value & execution)	5							
Series GYM GYM (value & execution)	5							

Appendix 3.3

CHOREOGRAPHY		0	1	2	3	4	5	6
Sissone	4							
Split leap forward	4							
Split leap forward 1/4 turn	3							
Split leap change leg	4							
Scissors leap forward 1/2 turn	4							
1/1 turn passe to develope	6							
2/1 spin	5							
Jump with 1/1 turn	6							
Jump with 2/1 turn	5							
Straddle pike jump	6							
Straddle jump	5							
Hop with 1/2 turn one leg extended	4							
Side split	5							
Cross split - right	5							
Cross split - left	4							

Appendix 3.4

F.I.G. Code of Points

Requirements for Modified Code

Value Parts	3.00
Bonus Points	1.00
Special Requirements	1.20
Composition	0.60
Execution & presentation	4.00

Value Parts

3 x A	0.60
3 x B	1.20
2 x C	1.20
	3.00

Special Requirements

Bars	**Beam**	**Floor**
bar change	acro series (2 flight elements)	two acrobatic series
bar change	gymnastic series	combination series
bar change	mixed series	3 different somersaults
flight element B	low element or connection	gymnastic series
different flight B	360° spin	mixed series
element with LA turn	large leap, jump or hop	gymnastic C
B dismount	B dismount	B dismount

Appendix 3.5

Resp no.	comp score (IGA/BSGA)	comp score (%)	TSA score	TSA score (%)	combined percentage
41	33.850	100.00	94.59	100.00	100.00
23	33.000	97.49	83.09	87.84	92.66
42	31.375	92.69	83.01	87.75	90.22
39	31.375	92.69	82.98	87.72	90.20
43	31.587	93.31	80.71	85.32	89.32
37	29.975	88.55	81.43	86.09	87.32
40	30.239	89.33	80.20	84.78	87.06
44	31.325	92.54	74.59	78.85	85.69
36	29.810	88.06	78.45	82.93	85.50
48	27.325	80.72	79.60	84.15	82.44
08	28.758	84.96	74.15	78.39	81.67
38	28.775	85.01	74.02	78.26	81.63
35	26.637	78.69	72.17	76.29	77.49
17	27.168	80.26	67.66	71.53	75.90
21	27.107	80.08	67.42	71.27	75.67
33	26.387	77.95	68.05	71.94	74.95
20	27.000	79.76	66.15	69.93	74.85
22	27.675	81.76	59.46	62.86	72.31
25	26.450	78.14	60.78	64.26	71.20
03	25.475	75.26	62.15	65.70	70.48
02	26.225	77.47	59.25	62.63	70.05
18	25.520	75.39	60.94	64.42	69.91
01	26.375	77.92	57.93	61.25	69.58
32	24.112	71.23	63.44	67.06	69.15
14	24.974	73.78	58.71	62.07	67.92
10	24.968	73.76	58.69	62.04	67.90
29	23.500	69.42	61.93	65.47	67.45
05	24.350	71.94	59.40	62.79	67.36
34	23.625	69.79	61.35	64.86	67.33
06	24.600	72.67	53.97	57.05	64.86
26	25.275	74.67	50.14	53.00	63.84
13	23.018	68.00	50.73	53.63	60.81
19	21.525	63.59	54.74	57.87	60.73

APPENDIX 4

APPENDIX 4.1: Questionnaire (gymnast)

APPENDIX 4.2: Questionnaire (parent)

APPENDIX 4.3: Questionnaire (coach)

APPENDIX 4.4: Completed training diaries

Questionnaire - Gymnast

Respondent number .....

Name ..... Date of Birth .....

Club..... Coach .....

Section 1 - personal details

1. How many sisters do you have? ..... How old are they? .....
.....
.....
.....

2. How many brothers do you have? ..... How old are they? .....
.....
.....
.....

3. Do you have a brother or sister who is a gymnast or who competes in gymnastic competitions?

☐ Yes
☐ No

4. If yes, who: Brother / Sister (please circle)

5. Did your mum or dad ever compete in a gymnastics competition?

- [ ] Yes
- [ ] No
- [ ] Unsure

6. If yes, who? Mum / Dad (please circle)

7. Did you decide you wanted to try gymnastics?

- [ ] Yes
- [ ] No

If yes, why did you decide to try gymnastics?

.....

.....

.....

.....

8. If no, who decided that you should try gymnastics?

- [ ] your mum
- [ ] your dad
- [ ] your coach
- [ ] a school teacher
- [ ] some other person, please state who

.....

.....

Section 2 - gymnastic history

9. How old were you when you first started gymnastics at a gym club?

.....

10. At which club did you first begin gymnastics ?

.....

11. When you first started gymnastics how many hours did you train every week ?

.....

12. What kind of training did you do?

	none		*some*		*alot*
	1	*2*	*3*	*4*	*5*
Vault	1	2	3	4	5
Bars	1	2	3	4	5
Beam	1	2	3	4	5
Floor	1	2	3	4	5
Choreography / dance	1	2	3	4	5
Conditioning	1	2	3	4	5
Flexibility	1	2	3	4	5

Section 3 - current gymnastic training

13. Do you enjoy practising gymnastics?

not at all	*a little*	*sort of*	*pretty much*	*very much*
1	*2*	*3*	*4*	*5*

14. Do you have fun practising gymnastics?

not at all	*a little*	*sort of*	*pretty much*	*very much*
1	*2*	*3*	*4*	*5*

15. How many times do you train every week?

.....

16. How many hours do you train every week?

.....

17. I think I train ....

too little		just right		too much
1	2	3	4	5

18. At what time of day do you usually train?

- [ ] in the morning
- [ ] during the day
- [ ] in the evening

19. Do you like the time at which you usually train?

- [ ] Yes
- [ ] No

If no, please explain why you do not like to train at this time :

.....

.....

.....

20. Do you like the gym in which you usually train?

- [ ] Yes
- [ ] No

If no, please explain why you do you not like the gym :

.....

.....

.....

21. Which is your favourite piece of apparatus in training?

- [ ] vault
- [ ] bars
- [ ] beam
- [ ] floor
- [ ] dance
- [ ] flexibility
- [ ] conditioning

22. Which is your least favourite piece of apparatus in training?

- [ ] vault
- [ ] bars
- [ ] beam
- [ ] floor
- [ ] dance
- [ ] flexibility
- [ ] conditioning

23. How much do you like the following types of training?

	dislike alot	*dislike*	*o.k*	*like*	*like alot*
	1	*2*	*3*	*4*	*5*
Vault	1	2	3	4	5
Bars	1	2	3	4	5
Beam	1	2	3	4	5
Floor	1	2	3	4	5
Choreography / dance	1	2	3	4	5
Conditioning	1	2	3	4	5
Flexibility	1	2	3	4	5

24. What type of coaching do you prefer?

- [ ] the coach working with you on your own
- [ ] being coached as part of a group

25. Do you practice gymnastics at home?

☐ Yes
☐ No

If yes, what do you practice at home?

.....

.....

.....

Section 4 - competition

26. Have you ever competed in a gymnastics competition before?

☐ Yes
☐ No

27. If yes, do you enjoy competing in gymnastics?

not at all	*a little*	*sort of*	*pretty much*	*very much*
1	*2*	*3*	*4*	*5*

28. Do you have fun competing in gymnastics?

not at all	*a little*	*sort of*	*pretty much*	*very much*
1	*2*	*3*	*4*	*5*

29. Which is your favourite piece of apparatus in competition?

☐ vault
☐ bars
☐ beam
☐ floor
☐ range & conditioning

30. Which is your least favourite piece of apparatus in competition?

- [ ] vault
- [ ] bars
- [ ] beam
- [ ] floor
- [ ] range & conditioning

Section 5 - friends

31. Do you like training with the people in your squad?

- [ ] Yes
- [ ] No
- [ ] Unsure

32. Are your best friends from:

- [ ] school
- [ ] gym
- [ ] other, please give details

.....

.....

.....

33. Do you regularly watch other members of your group or squad in competition?

- [ ] Yes
- [ ] No

34. Have you ever been to watch a national or international gymnastic competition?

- [ ] Yes
- [ ] No

35. Would you like to go to watch a national or international gymnastic competition?

- [ ] Yes
- [ ] No

36. Do you watch gymnastics when it is on television?

- [ ] always
- [ ] sometimes
- [ ] never

Section 6 - other interests

37. Do you take part in other sports apart from gymnastics?

- [ ] Yes
- [ ] No

38. If yes, what other sports do you practice?

.....

.....

.....

39. Do you train regularly for these other sports (at least once a week) ?

- [ ] Yes
- [ ] No

40. If yes, how often do you practice these other sports?

- [ ] once per week
- [ ] 2-3 times per week
- [ ] 4 or more times per week

41. What other things do you do apart from sport?

.....

.....

.....

42. Does training or competing in gymnastics interfere with doing your other sports or hobbies?

- [ ] always
- [ ] sometimes
- [ ] never

43. Does training or competing in gymnastics ever interfere with your school work?

- [ ] always
- [ ] sometimes
- [ ] never

THANK YOU FOR COMPLETING THESE QUESTIONS.

Questionnaire - Parents

Name ..... Mother/Father*

*please delete as appropriate

Name of daughter .....

Date ..... Resp no. .....

Section 1 - gymnastic history

1. How old was your daughter when she began gymnastics?

.....

.....

2. Do you think this was:

too young		about right		too old
1	2	3	4	5

3. Whose decision was it for your daughter to try gymnastics?

- [ ] yourself or your partner
- [ ] your daughter
- [ ] coach
- [ ] teacher
- [ ] some other person, please state who

.....

.....

4. At what age did your daughter begin more serious gymnastic training (more than two times per week)?

.....

.....

5. Do you think this was:

too young		about right		too old
1	2	3	4	5

6. Who made the decision that your daughter would begin training more seriously?

- [ ] yourself or your partner
- [ ] your daughter
- [ ] coach
- [ ] teacher
- [ ] some other person, please state who

7. Are you involved in gymnastics, other than as the parent of a gymnast?

- [ ] Yes
- [ ] No

If yes, please give details

.....

.....

.....

.....

8. Were you involved in gymnastics before your daughter took up the sport?

- [ ] Yes
- [ ] No

9. Did you ever do gymnastics yourself? (If no, go to question 11)

- [ ] Yes
- [ ] No

10. To what level did you participate?

- [ ] recreational
- [ ] school
- [ ] club
- [ ] county
- [ ] regional
- [ ] national / international

Section 2 - Gymnastic Interests

11. Do you go to gymnastic competitions to watch your daughter compete?

- [ ] always
- [ ] sometimes
- [ ] never

12. Do you go to gymnastic competitions in which your daughter does not compete?

- [ ] always
- [ ] sometimes
- [ ] never

13. Do you participate in your daughter's gym club activities (eg fund raising events) ?

- [ ] always
- [ ] sometimes
- [ ] never

14. Do you watch gymnastics on T.V. with your daughter?

- [ ] always
- [ ] sometimes
- [ ] never

Section 3- Family interests

15. Do you have any other children?

☐ Yes
☐ No If no, please go to question 22.

16. How many other children do you have?

.....

.....

17. Are any of your other children involved in gymnastics?

☐ Yes
☐ No If yes, please give details below:

.....

.....

.....

18. Do any of your other children participate in an organised sport (more than twice per week) ?

☐ Yes
☐ No If yes, please give details below:

.....

.....

.....

19. Do any of your other children participate regularly in other interests (more than twice per week) ?

☐ Yes
☐ No If yes, please give details below:

.....

.....

.....

20. Do the demands of your daughter's gymnastic training ever restrict the activities of your other children?

☐ Yes
☐ No

If yes, please give details

.....

.....

.....

21. Does your daughter's gymnastic training ever interfere with other family activities?

☐ Yes
☐ No

If yes, please give details

.....

.....

.....

22. Does your daughter's gymnastic training ever limit the other activities/ interests she is able to pursue?

☐ Yes
☐ No

If yes, please give details

.....

.....

.....

23. Would you consider that you daughter's gymnastic training takes priority over other family events?

☐ always
☐ sometimes
☐ never

24. Would you consider that you daughter's gymnastic competitions take priority over other family events?

- ☐ always
- ☐ sometimes
- ☐ never

25. Does your daughter's gymnastic training ever interfere with her school work?

- ☐ Yes
- ☐ No

Section 4 - Travel and Finance

26. How much are the fees to train for these gymnasts? (Please specify the time interval the fees cover)

.....

.....

.....

.....

27. In comparison to other sports and activities, do you think that these fees are:

very cheap	**cheap**	**about right**	**expensive**	**very expensive**
1	**2**	**3**	**4**	**5**

28. How far do you travel to take your daughter to gymnastics training?

..... miles

..... minutes

29. Do you have to wait for your daughter at the gymnasium while she is training?

- ☐ always
- ☐ sometimes
- ☐ never

If never, please go to question 31.

30. Is this a major inconvenience for you?

- [ ] Yes
- [ ] No

31. Do you share travelling time with other parents?

- [ ] Yes
- [ ] No

Section 5 - Enjoyment & Interest

32. Do you think your daughter is happy doing gymnastics?

- [ ] Yes
- [ ] No
- [ ] Unsure

33. Are you happy that your daughter is doing gymnastics?

- [ ] Yes
- [ ] No

If no, please give details below:

.....

.....

.....

.....

34. Would you be disappointed if your daughter decided to give up gymnastics?

- [ ] Yes
- [ ] No

35. Do you think your daughter enjoys competing?

- [ ] Yes
- [ ] No
- [ ] Unsure

36. Do you enjoy watching your daughter compete?

- [ ] Yes
- [ ] No
- [ ] Unsure

Section 6 - Aspirations

37. Do you consider you daughter to be talented in gymnastics?

- [ ] Yes
- [ ] No
- [ ] Unsure

38. What do you hope your daughter will achieve in gymnastics?

.....

.....

.....

.....

.....

.....

39. What do you hope your daughter will gain from her gymnastic experience?

.....

.....

.....

.....

.....

.....

Please fill in the following information to the best of your ability, please indicate in the box after each response whether the information you have provided is an accurate measurement (A) or an approximate estimation (E).

	Feet/Inches	Metres/cms	A/E
Height of gymnast's biological mother	.....	.....	☐
Height of gymnast's biological father	.....	.....	☐
Height of gymnast's maternal grandmother	.....	.....	☐
Height of gymnast's maternal grandfather	.....	.....	☐
Height of gymnast's paternal grandmother	.....	.....	☐
Height of gymnast's paternal grandfather	.....	.....	☐

THANK YOU FOR COMPLETING THESE QUESTIONS.

Appendix 4.3

Questionnaire - Coach

Name of coach..... Level.....

Club.....

Gymnasts involved in the study

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Name ..... Respondent no. .....

Section 1 - participation and training

1. How old are gymnasts when they begin recreational gymnastics at your club?

.....

.....

2. How old are the gymnasts when they begin more serious training? (more than 2 times per week)

.....

.....

3. How many 8-10 year old gymnasts train above recreational level at your club?

(1986-1988 birth date)

1986 (10) .....

1987 (9) .....

1988 (8) .....

4. On average, how many times per week/hours per week do these gymnast train?

1986	No of times	.....
	Total hours	.....
1987	No of times	.....
	Total hours	.....
1988	No of times	.....
	Total hours	.....

5. How much are the fees to train for these gymnasts? (please indicate period of time)

.....

.....

6. Does the majority of the coaching of 8-10 year old gymnasts take the form of:

- [ ] Group instruction
- [ ] Individual instruction
- [ ] Other, please give details

.....

.....

.....

7. Please indicate the average group size for 8-10 year old gymnasts

.....

.....

8. Is your facility

- [ ] Privately owned
- [ ] Local Authority
- [ ] Other, please give details

.....

.....

.....

9. Is your training limited by any constraints?

- [ ] Yes
- [ ] No

If yes, please give details below:

.....

.....

.....

10. Does the facility at which you train most often contain all the equipment you require for your gymnast's training?

- [ ] Yes
- [ ] No

If No, please give details below:

.....

.....

.....

Section 2 - Programming

11. Do you programme your gymnasts' preparation?

- [ ] Yes
- [ ] No

12. Does your programme set targets for:

- [ ] each apparatus
- [ ] each training session
- [ ] each week
- [ ] every month
- [ ] a 3-6 month period
- [ ] a year
- [ ] other, please give details

N.B. you may tick more than one box:

.....

.....

.....

13. Are the programmes set for:

- [ ] everyone in the club to follow
- [ ] groups of gymnasts to follow
- [ ] each individual gymnast
- [ ] other, please give details

.....

.....

.....

14. Are the programmes based upon :

- [ ] quantity
- [ ] quality
- [ ] quantity or quality
- [ ] nature of work
- [ ] other

If other, please give details below:

.....

.....

.....

15. Do you monitor that the programme is being followed?

☐ Yes
☐ No

If yes, please give details below:

.....

.....

.....

16. Do you evaluate the success of your programmes?

☐ Yes
☐ No

If yes, please give details below:

.....

.....

.....

Section 3 - Identification of talent

17. How did the majority of your current 8-10 year old gymnasts come to join your club?

.....

.....

.....

18. Do you actively recruit children to join your gymnastics club?

☐ Yes
☐ No

If yes, please give details

.....

.....

.....

19. Do you consider that in the operation of your gymnastics club you use any form of talent identification?

☐ Yes
☐ No

If yes, please give details below:

.....

.....

.....

20. What do you consider to be most important attributes in the initial identification of a young gymnast? (please list the factors according to their importance, most important first).

.....

.....

.....

.....

.....

21. At what age do you consider this initial identification should be made?

.....

.....

.....

22. What do you consider to be most important attributes in the ideal 8-10 year old gymnast?

.....

.....

.....

.....

.....

23. Do you think you are proficient in the art of talent identification?

☐ Yes
☐ No
☐ Unsure

24. Do you think British Gymnastics would benefit if national guidelines were published on the subject of talent identification?

- [ ] Yes
- [ ] No
- [ ] Unsure

25. Please list any comments you may have relating to the identification and development of gymnastic talent.

.....

.....

.....

.....

.....

.....

THANK YOU FOR COMPLETING THESE QUESTIONS.

Appendix 4.4

Record of Training

Respondent number .....

Name ..... Date of Birth .....

Club..... Coach .....

Key

Date	Monday - Sunday
Duration	Duration of session (hours)
Type	Club, County, Regional, National
Nature	W = warm-up *E* = individual elements *P* = progressions *Vr* = volunatry routines *Gr* = grade routines *Vc* = voluntary combinations *Gc* = grade combinations *Cp* = complex (beam / floor) *D* = dance (choreography) *T* = testing *O* = other (please specify)
Instruction	*P* = Personal Instruction *G* = group Instruction
Duration	Time on each apparatus / activity (minutes)
Elements	number of elements **completed**

Respondent number .....37..... *Week commencing Monday* .....3.Feb.97.....
Date .....3.Feb.97..... Duration .....3½.hrs..... Type .....Club.....

	Nature	Instruction	Duration	Elements
Warm-up	W	G	15 min	
Vault	P	P/G	30 min	10
Bars	Gr/Vc	P/G	30 min	108
Beam	Cp/Gc	P/G	30 min	88
Floor				
Range & Conditioning	Gr	P	30 min	70
Tumbling				
Choreography				
Flexibility		G	10 min	
Conditioning		G/P	35 min	432
Other		G	30 min	213

Date .....4.Feb.97..... Duration .....3½.hrs..... Type .....Club.....

	Nature	Instruction	Duration	Elements
Warm-up	W	G	15 min	
Vault	Gr/P	P/G	35 min	10
Bars	Gr/Vc	P/G	40 min	63
Beam				
Floor				
Range & Conditioning				
Tumbling	Gc	P/G	40 min	45
Choreography				
Flexibility		G	10 min	
Conditioning		G/P	35 min	432
Other		G	35 min	260

Date .....5.Feb.97..... Duration .....3½.hrs..... Type .....Club.....

	Nature	Instruction	Duration	Elements
Warm-up	W	G	15 min	
Vault				
Bars	Gr/Vc	P/G	40 min	76
Beam	Gr/Vc/Cp	P/G	40 min	122
Floor				
Range & Conditioning				
Tumbling	Gc	P/G	35 min	37
Choreography				
Flexibility		G	10 min	
Conditioning		G/P	35 min	378
Other		G	35 min	276

Date .....6.Feb.97..... Duration .....Rest.Day..... Type .....Club.....

	Nature	Instruction	Duration	Elements
Warm-up				
Vault				
Bars				
Beam				
Floor				
Range & Conditioning				
Tumbling				
Choreography				
Flexibility				
Conditioning				
Other				

Date .....7.Feb.97..... Duration .....3½.hrs..... Type .....Club.....

	Nature	Instruction	Duration	Elements
Warm-up	W	G	15 min	
Vault	Vr/P	P/G	30 min	10
Bars	Gr/Vc	P/G	30 min	74
Beam	Cp/Gr/Vc	P/G	35 min	139
Floor				
Range & Conditioning				
Tumbling	P/Gr	P/G	20 min	55
Choreography			10 min	43
Flexibility		G	10 min	
Conditioning		G	30 min	374
Other		G	30 min	222

Date .....8.Feb.97..... Duration .....4.hrs..... Type .....Club.....

	Nature	Instruction	Duration	Elements
Warm-up	W	G	15 min	
Vault				
Bars				
Beam				
Floor				
Range & Conditioning		P	10 min	20
Tumbling	Gc	P/G	25 min	45
Choreography	D	P	100 min	
Flexibility		G	10 min	
Conditioning		G/P	30 min	374
Other		G	50 min	328

Date .....9.Feb.97..... Duration .....3½.hrs..... Type .....Regional.Squad...

	Nature	Instruction	Duration	Elements
Warm-up	W	G	15 min	
Vault	P/Vc	G/P	25 min	11
Bars	Gr/Vc	G/P	25 min	51
Beam	Cp/Gc/Vc	G/P	25 min	118
Floor				
Range & Conditioning				
Tumbling	Vc	G/P	25 min	88
Choreography				
Flexibility	circuit	G/P	25 min	
Conditioning		G/P	35 min	374
Other		G	90 min	440

APPENDIX 5

APPENDIX 5.1: Anthropometric proforma (Yeadon, 1990b)

APPENDIX 5.2: COM calculation

APPENDIX 5.3: Standardised warm-up

APPENDIX 5.4: Set-up files for functional flexibility

APPENDIX 5.5: Descriptive data for physical talent characteristics

Appendix 5.1

ANTHROPOMETRIC MEASUREMENTS FOR SEGMENTAL INERTIA PARAMETERS

NAME	subject 001	AGE	10.26	HEIGHT	1.360 m	DATE	13/09/96
MEASURER	J.P.			WEIGHT	29.76 kg		

All measurements in millimetres

TORSO

level	hip	umbilicus	ribcage	nipple	shoulder	neck		nose	ear	top
length	0	158	221	373	445	490	0	77	126	212
perimeter	694	581	606	692		275		398	491	
width	240	203	208	223	226					
depth					122					

LEFT ARM

level	shoulder	midarm	elbow	forearm	wrist		thumb	knuckle	nails
length	0		230	277	427	0	58	85	157
perimeter	241	199	186	192	127		185	152	89
width					47		75	64	34

RIGHT ARM

level	shoulder	midarm	elbow	forearm	wrist		thumb	knuckle	nails
length	0		230	277	427	0	58	85	157
perimeter	241	199	186	192	127		185	152	89
width					47		75	64	34

LEFT LEG

level	hip	crotch	midthigh	knee	calf	ankle		heel	arch	ball	nails
length	0	68		312	410	628	0	22		108	176
perimeter		412	334	258	266	191		252	192	186	117
width										75	45
depth								93			

RIGHT LEG

level	hip	crotch	midthigh	knee	calf	ankle		heel	arch	ball	nails
length	0	68		312	410	628	0	22		108	176
perimeter		412	334	258	266	191		252	192	186	117
width										75	45
depth								93			

Appendix 5.2

Manual Calculation of Vertical Location of Mass Centre
Subject 001 September 1996

Spatial coordinates

	sway
L_Toey	0.2115
L_Toez	-0.0473
L_Heely	0.2174
L_Heelz	0.0248
L_Ankley	0.2255
L_Anklez	0.093
L_Kneey	0.2073
L_Kneez	0.3536
L_Hipy	0.2055
L_Hipz	0.6958
L_Shouldy	0.2479
L_Shouldz	1.0191
L_Elbowy	0.2936
L_Elbowz	0.789
L_Wristy	0.2311
L_Wristz	0.6308
R_Toey	-0.0621
R_Toez	0.0972
R_Heely	0.0278
R_Heelz	0.1167
R_Ankley	0.029
R_Anklez	0.1317
R_Kneey	-0.0208
R_Kneez	0.4282
R_Hipy	-0.0701
R_Hipz	0.7527
R_Shouldy	-0.1228
R_Shouldz	1.154
R_Elbowy	-0.17
R_Elbowz	0.9334
R_Wristy	-0.1381
R_Wristz	0.744
Heady	0.0661
Headz	1.2629
Image	-1
Time	19:50:20:00

	trunk	thigh	calf	foot	head	arm	farm
Segment length	0.5262	0.4058	0.4474	0.5974	0.7986	0.4551	0.6476
Segment mass	0.4622	0.1098	0.0506	0.0144	0.0914	0.0268	0.0216

RIGHT	mass	up coord	length ratio	up coord	low coord	centre of mass
foot	0.0144	0.1317	0.5974	0.1317	0.0972	0.001599692
lower leg	0.0506	0.4282	0.4474	0.4282	0.1317	0.014954623
thigh	0.1098	0.7527	0.4058	0.7527	0.4282	0.068187765
upper arm	0.0268	1.154	0.4551	1.154	0.9334	0.028236612
lower arm & hands	0.0216	0.9334	0.6476	0.9334	0.744	0.017512082
LEFT						
foot	0.0144	0.093	0.5974	0.093	-0.0473	0.000132261
lower leg	0.0506	0.3536	0.4474	0.3536	0.093	0.011992583
thigh	0.1098	0.6958	0.4058	0.6958	0.3536	0.061151489
upper arm	0.0268	1.0191	0.4551	1.0191	0.789	0.024505424
lower arm & hands	0.0216	0.789	0.6476	0.789	0.6308	0.014829473
TORSO	0.4622	1.08655	0.5262	1.08655	0.72425	0.422863203
HEAD & NECK	0.0914	1.2629	0.7986	1.2629	1.08655	0.112182816

av shoulder coordinate	1.08655	Manual	whole body CM	0.778
average hip coordinate	0.72425	Program	whole body CM	0.775

Appendix 5.3

Standardized 4 minute warm-up

Jog on spot 1 minute
10 tuck jumps
Jog on spot 30 seconds
Knee's lifted 10 seconds

Circle right arm x 5 forwards
Circle left arm x 5 forwards
Circle both arms x 5 forwards

Circle right arm x 5 backwards
Circle left arm x 5 backwards
Circle both arms x 5 backwards

with feet in straddle, hands on hips circle hips x 5 each way

Side bends x 5 each way

Stretch up, hands on floor forwards, between legs, backwards x 5 each way

Straddle sit - bend left, bend right x 5
straddle forward fold
legs together, forward fold

Seated shoulder stretches - arms shoulder width apart

Lunges, right, left, side
Splits

Circle wrists, kneel and warm-up wrists
Circle ankles, stretch ankles, 2 distances from the wall

Gentle bridge x2 - roll afterwards.

Appendix 5.4

Shoulder Flexion (SFX)

08 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Relbo
002 1 Rshou
003 1 RFleo
004 1 RBleo
005 2 Relbo
006 2 Rshou
007 2 RFleo
008 2 RBleo
10 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D004 1
D002 1
M005 3
D006 3
D007 3
D008 3
D006 3
end

Shoulder Extension (SXT)

08 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Relbo
002 2 Rshou
003 3 RFleo
004 4 RBleo
005 5 Relbo
006 6 Rshou
007 1 RFleo
008 2 RBleo
10 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D004 1

D002 1
M005 3
D006 3
D007 3
D008 3
D006 3
end

Bridge (BRG)

04 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Rwris
002 2 Rshou
003 3 Rwris
004 4 Rshou
4 Number of drawing instructions(symbol,no. col)
M001 6
D002 6
M003 7
D004 7
end

Seated Forward Fold (FFD)

10 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 T12up
002 2 T12lw
003 3 RFleo
004 4 RBleo
005 5 Rknee
006 6 T12up
007 1 T12lw
008 2 RFleo
009 3 RBleo
010 4 Rknee
12 Number of drawing instructions(symbol,no. col)
M001 5
D002 5
M003 5
D004 5
D005 5
D003 5

M006 7
D007 7
M008 7
D009 7
D010 7
D008 7
end

Straddle Forward Fold (SFD)

08 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 lineF
002 2 lineB
003 3 T12up
004 4 T12lw
005 5 LineF
006 6 LineB
007 1 T12up
008 2 T12lw
08 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
M003 1
D004 1
M005 3
D006 3
M007 3
D008 3
end

Wrist Flexion (WFX)

06 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Relbo
002 2 Rwris
003 3 Rfing
004 4 Relbo
005 5 Rwris
006 6 Rfing
06 Number of drawing instructions(symbol,no. col)
M001 1
D002 1

D003 1
M004 6
D005 6
D006 6
end

Ankle Plantar Flexion (APF)

06 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 RKnee
002 2 Rmall
003 3 Rtoe
004 4 Rknee
005 5 Rmall
006 6 Rtoe
06 Number of drawing instructions(symbol,no. col)
M001 5
D002 5
D003 5
M004 1
D005 1
D006 1
end

D angle (D1_)

06 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 RFleo
002 2 RBleo
003 3 Rknee
004 4 RFleo
005 5 RBleo
006 6 Rknee
08 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D001 1
M004 3
D005 3
D006 3
D004 3
end

Lift & Hold Right Leg Front (FRR)

12 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Rshou
002 2 RTleo
003 3 RBleo
004 4 Rknee
005 5 Rankl
006 6 Lknee
007 1 Rshou
008 2 RTleo
009 3 RBleo
010 4 Rknee
011 5 Rankle
012 6 LKnee
14 Number of drawing instructions(symbol,no. col)
M001 1
D006 1
M005 1
D004 1
D003 1
D002 1
D004 1
M007 3
D012 3
M011 3
D010 3
D009 3
D008 3
D010 3
end

Lift & Hold Right Leg Side (SDR)

18 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Rshou
002 2 Lshou
003 3 LTleo
004 4 LBleo
005 5 Lknee
006 6 RTleo
007 7 RBleo
008 8 Rknee

009 9 Rankle
010 10 Rshou
011 11 Lshou
012 12 LTleo
013 13 LBleo
014 14 Lknee
015 15 RTleo
016 16 RBleo
017 17 Rknee
018 18 Rankl
22 Number of drawing instructions(symbol,no. col)
M001 1
M002 1
M005 1
D003 1
D004 1
D005 1
M009 1
D008 1
M006 1
D007 1
D008 1
M010 4
M011 4
M014 4
D012 4
D013 4
D014 4
M018 4
D017 4
D015 4
D016 4
D017 4
end

Lift & Hold Back Leg Right

08 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Rshou
002 2 RFleo
003 3 RBleo
004 4 Rknee
005 5 Rshou
006 6 RFleo
007 7 RBleo

008 8 Rknee
16 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D001 1
M004 1
D002 1
D003 1
D004 1
M005 3
D006 3
D007 3
D005 3
M008 3
D006 3
D007 3
D008 3
end

Lift & Hold Left Leg Front (FRL)

12 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Lshou
002 2 LTleo
003 3 LBleo
004 4 Lknee
005 5 Lankl
006 6 Rknee
007 1 Lshou
008 2 LTleo
009 3 LBleo
010 4 Lknee
011 5 Lankle
012 6 RKnee
14 Number of drawing instructions(symbol,no. col)
M001 1
D006 1
M005 1
D004 1
D003 1
D002 1
D004 1
M007 3
D012 3

M011 3
D010 3
D009 3
D008 3
D010 3
end

Lift & Hold Left Leg Side (SDL)

18 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Rshou
002 2 Lshou
003 3 RTleo
004 4 RBleo
005 5 Rknee
006 6 LTleo
007 7 LBleo
008 8 Lknee
009 9 Lankle
010 10 Rshou
011 11 Lshou
012 12 RTleo
013 13 RBleo
014 14 Rknee
015 15 LTleo
016 16 LBleo
017 17 Lknee
018 18 Lankl
22 Number of drawing instructions(symbol,no. col)
M001 1
M002 1
M005 1
D003 1
D004 1
D005 1
M009 1
D008 1
M006 1
D007 1
D008 1
M010 4
M011 4
M014 4
D012 4
D013 4

D014 4
M018 4
D017 4
D015 4
D016 4
D017 4
end

Lift & Hold Back Leg Right (BKR)

08 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Lshou
002 2 LFleo
003 3 LBleo
004 4 Lknee
005 5 Lshou
006 6 LFleo
007 7 LBleo
008 8 Lknee
16 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D001 1
M004 1
D002 1
D003 1
D004 1
M005 3
D006 3
D007 3
D005 3
M008 3
D006 3
D007 3
D008 3
end

Splits Right (SPR)

12 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 RKnee

002 2 RTleo
003 3 RBleo
004 4 LTleo
005 5 LBleo
006 6 LKnee
007 1 RKnee
008 2 RTleo
009 3 RBleo
010 4 LTleo
011 5 LBleo
012 6 LKnee
16 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D001 1
M004 1
D005 1
D006 1
D004 1
M007 3
D008 3
D009 3
D007 3
M010 3
D011 3
D012 3
D010 3
end

Splits Left (SPL)

12 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 LKnee
002 2 LTleo
003 3 LBleo
004 4 RTleo
005 5 RBleo
006 6 RKnee
007 1 LKnee
008 2 LTleo
009 3 LBleo
010 4 RTleo
011 5 RBleo
012 6 RKnee

16 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D001 1
M004 1
D005 1
D006 1
D004 1
M007 3
D008 3
D009 3
D007 3
M010 3
D011 3
D012 3
D010 3
end

Split Jump Right (SJR)

14 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Rankl
002 2 Rknee
003 3 RTleo
004 4 RBleo
005 5 LTleo
006 6 LBleo
007 7 LKnee
008 8 Rankle
009 9 RKnee
010 10 RTleo
011 11 RBleo
012 12 LTleo
013 13 LBleo
014 14 LKnee
18 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D004 1
D002 1
M005 1
D006 1
D007 1

D005 1
M008 3
D009 3
D010 3
D011 3
D009 3
M012 3
D013 3
D014 3
D012 3
end

Split Jump Left (SJL)

14 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 Lankl
002 2 Lknee
003 3 LTleo
004 4 LBleo
005 5 RTleo
006 6 RBleo
007 7 RKnee
008 8 Lankle
009 9 LKnee
010 10 LTleo
011 11 LBleo
012 12 RTleo
013 13 RBleo
014 14 RKnee
18 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D004 1
D002 1
M005 1
D006 1
D007 1
D005 1
M008 3
D009 3
D010 3
D011 3
D009 3
M012 3

D013 3
D014 3
D012 3
end

Handstand Split Right (HSR)

12 total number of points per frame
00 number of reference frames
2 time per frame read off video
001 1 RKnee
002 2 RFleo
003 3 RBleo
004 4 LFleo
005 5 LBleo
006 6 LKnee
007 1 RKnee
008 2 RFleo
009 3 RBleo
010 4 LFleo
011 5 LBleo
012 6 LKnee
16 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D001 1
M004 1
D005 1
D006 1
D004 1
M007 3
D008 3
D009 3
D007 3
M010 3
D011 3
D012 3
D010 3
end

Handstand Split Left (HSL)

12 total number of points per frame
00 number of reference frames
2 time per frame read off video

001 1 LKnee
002 2 LFleo
003 3 LBleo
004 4 RFleo
005 5 RBleo
006 6 RKnee
007 1 LKnee
008 2 LFleo
009 3 LBleo
010 4 RFleo
011 5 RBleo
012 6 RKnee
16 Number of drawing instructions(symbol,no. col)
M001 1
D002 1
D003 1
D001 1
M004 1
D005 1
D006 1
D004 1
M007 3
D008 3
D009 3
D007 3
M010 3
D011 3
D012 3
D010 3
end

Appendix 5.5

Anthropometric variables (all gymnasts, n=33)

	mean ± SD	minimum	maximum
height (m)	1.300 ± 0.054	1.159	1.338
sitting height (m)	0.684 ± 0.029	0.621	0.730
sitting height to stature ratio (%)	52.62 ± 0.009	50.6	54.1
mass (kg)	26.7 ± 2.8	21.0	32.2
BMI (kg/m^2)	15.72 ± 0.83	14.44	18.11
upper leg length (cm)	34.0 ± 1.9	30.5	37.3
lower leg length (cm)	28.5 ± 1.8	23.8	32.7
foot length (cm)	20.3 ± 1.0	17.8	22.1
upper arm length (cm)	24.7 ± 1.3	22.0	27.6
lower arm length (cm)	17.6 ± 1.1	14.3	19.5
hand length (cm)	15.0 ± 0.8	12.9	16.2
biacromial width (cm)	28.6 ± 1.8	25.9	31.9
biiliac width (cm)	19.9 ± 0.9	17.7	21.6
biacromial to biiliac ratio (%)	143.8 ± 6.1	132	156
armspan (m)	1.32 ± 6.80	1.173	1.461
armspan to stature ratio (%)	101.7 ± 1.9	93.7	106
wrist width (cm)	4.5 ± 0.2	4.1	5.0
knee width (cm)	7.6 ± 0.3	6.8	8.1
ankle width (cm)	5.8 ± 0.3	5.0	6.4
elbow width (cm)	5.3 ± 0.3	4.7	5.7
predicted adult height (m)	1.612 ± 0.039	1.548	1.675

Moment of inertia variables (all gymnasts, n=33)

	mean ± SD	minimum	maximum
IF1 layout (kg/m^2)	3.55 ± 0.67	2.18	4.75
IF1 pike (kg/m^2)	1.34 ± 0.25	0.82	1.82
IF1 tuck (kg/m^2)	1.04 ± 0.20	0.64	1.41
IF3 wide arm (kg/m^2)	0.13 ± 0.02	0.08	0.18
IF3 straight (kg/m^2)	0.46 ± 0.09	0.28	0.65
IF1 pike as % layout (%)	37.76 ± 1.11	33.61	40.82
IF1 tuck as % layout (%)	29.43 ± 1.46	26.25	33.33
IF3 straight as % wide arm (%)	27.56 ± 1.91	24.32	30.77

Isometric strength variables (all gymnasts, n=33)

	mean ± SD	minimum	maximum
HXT ARFD (N/s)	1782 ± 948	206	3858
HXT MRFD (N/s)	2378 ± 1012	468	4656
HXT NMIF (N/kg)	10.68 ± 3.21	4.58	17.62
HXT NRFD (N/s)/(N/kg)	8.41 ± 2.15	3.44	11.88
SEL ARFD (N/s)	1005 ± 526	208	2393
SEL MRFD (N/s)	1903 ± 703	906	3406
SEL NMIF (N/kg)	14.10 ± 3.92	6.65	22.73
SEL NRFD (N/s)/(N/kg)	5.16 ± 1.62	2.57	11.63
SFX ARFD (N/s)	288 ± 158	115	700
SFX MRFD (N/s)	485 ± 195	93	874
SFX NMIF (N/kg)	3.27 ± 0.63	1.79	4.38
SFX NRFD (N/s)/(N/kg)	5.48 ± 1.49	0.85	9.73

Muscular power (jump) variables (all gymnasts, n=33)

	mean ± SD	min	max
DJ compression time (s)	0.11 ± 0.05	0.05	0.23
DJ force pre take off (N)	1385 ± 462	654	2793
DJ jump height (m)	0.196 ± 0.046	0.113	0.280
DJ normalised mean POF (N/kg)	25.9 ± 3.9	18.7	33.69
DJ NMPP (Nm/kgs)	31.8 ± 6.5	19.3	47.0
DJ NPPP (Nm/kgs)	54.7 ± 11.3	39.9	82.4
DJ PFdt (s)	0.158± 0.082	0.082	0.404
DJ peak jump height (m)	0.329 ± 0.073	0.206	0.502
DJ push-off impulse (Ns)	52.37 ± 9.60	35.75	71.54
DJ push-off time (s)	0.128 ± 0.035	0.080	0.216
DJ ratio impulse (%)	112.1 ± 22.9	62.0	177.0
DJ stretch height (m)	0.133 ± 0.064	0.001	0.326
Standing broad jump (m)	1.771 ± 0.170	1.465	2.180
Normalised standing broad jump (%)	136.9 ± 10.27	115.0	160.0
VJ compression time (s)	0.506 ± 0.125	0.304	0.760
VJ jump height (m)	0.278 ± 0.043	0.196	0.379
VJ normalised mean POF (N)	19.94 ± 3.60	13.91	26.89
VJ NMPP (Nm/kgs)	23.17 ± 9.29	6.0	38.0
VJ NPPP (Nm/kgs)	53.02 ± 6.02	43.4	64.0
VJ PFdt (s)	0.112 ± 0.013	0.076	0.140
VJ peak jump height (m)	0.392 ± 0.050	0.314	0.498
VJ peak force (N)	570.1 ± 152.9	350.8	940.2
VJ push-off impulse (Ns)	59.31 ± 8.57	44.10	77.35
VJ push-off time (s)	0.257 ± 0.119	0.128	0.548
VJ ratio impulse (%)	267 ± 63	174	413
VJ stretch height (m)	0.114 ± 0.027	0.024	0.156

Flexibility variables (all gymnasts, n=33)

Joint angle (°)	**mean ± SD**	**minimum**	**maximum**
CSER	215.1 ± 15.2	185.0	240.0
CWXT	89.0 ± 9.4	60.0	110.0
BOX SPLITS	167.1 ± 12.4	140.0	185.0
FAPF	156.8 ± 6.6	147.2	171.9
FBKAV	223.3 ± 9.4	199.1	238.6
FBRG	91.9 ± 12.7	71.6	119.2
FD1	90.9 ± 10.1	64.2	115.6
FFFD	120.8 ± 7.7	107.8	137.3
FFRAV	119.9 ± 15.7	90.3	156.5
FHSAV	151.1 ± 13.3	116.1	176.0
FSDAV	96.0 ± 13.7	69.0	130.9
FSFD	162.2 ± 9.7	141.3	176.6
FSFX	200.6 ± 13.0	173.2	232.6
FSJAV	151.6 ± 17.9	105.7	190.8
FSXT	87.2 ± 14.4	55.7	118.5
FWFX	104.9 ± 16.4	24.3	123.1

Local Muscular Endurance variables (all gymnasts, n=33)

Number of repetitions (n)	**mean ± SD**	**minimum**	**maximum**
Back-ups 10 s	7.2 ± 1.0	5.0	10.0
Back-ups 30 s	13.4 ± 2.6	13.0	24.0
Back-ups 60 s	33.6 ± 6.6	16.0	47.0
Leg dips 10 s average L& R	5.6 ± 1.2	3.5	8.0
Leg dips 30 s average L& R	14.0 ± 3.3	7.5	21.0
Leg dips 60 s average L& R	24.2 ± 5.9	12.0	35.0
Leg lifts 10 s	5.1 ± 0.3	5.0	6.0
Leg lifts 30 s	12.8 ± 1.4	9.0	16.0
Leg lifts 60 s	21.0 ± 3.6	12.0	28.0
Reverse leg lifts 10 s	7.7 ± 1.28	4.0	10.0
Reverse leg lifts 30 s	21.5 ± 4.5	9.0	30.0
Reverse leg lifts 60 s	40.5 ± 9.0	21.0	59.0
Straddle lever to handstand	3.9 ± 2.9	0.50	10.0

Anthropometric variables (successful, n=12 and unsuccessful gymnasts, n=21)

	successful mean ± SD	**unsuccessful mean ± SD**
height (m)	1.316 ± 0.060	1.292 ± 0.051
sitting height (m)	0.693 ± 0.027	0.679 ± 0.029
sitting height to stature ratio (%)	52.76 ± 0.008	52.54 ± 0.010
mass (kg)	27.95 ± 2.88	25.92 ± 2.58
BMI (kg/m^2)	16.13 ± 0.87	15.49 ± 0.74
upper leg length (cm)	34.3 ± 2.1	33.8 ± 1.8
lower leg length (cm)	28.8 ± 2.3	28.3 ± 1.5
foot length (cm)	20.5 ± 0.9	20.2 ± 1.0
upper arm length (cm)	25.1 ± 1.5	24.4 ± 1.2
lower arm length (cm)	17.8 ± 1.1	17.4 ± 1.1
hand length (cm)	15.2 ± 0.5	14.9 ± 0.8
biacromial width (cm)	29.3 ± 1.7	28.3 ± 1.7
biiliac width (cm)	20.1 ± 0.7	19.9 ± 1.0
biacromial to biiliac ratio (%)	148.9 ± 5.6	142.5 ± 6.5
armspan (m)	1.343 ± 0.076	1.312 ± 0.062
armspan to stature ratio (%)	102.1 ± 2.3	101.5 ± 1.6
wrist width (cm)	4.5 ± 0.2	4.5 ± 2.3
knee width (cm)	7.7 ± 0.3	7.5 ± 0.3
ankle width (cm)	6.0 ± 0.3	5.8 ± 0.3
elbow width (cm)	5.4 ± 0.2	5.3 ± 0.3
predicted adult height (m)	1.592 ± 0.031	1.624 ± 0.039

Moment of inertia variables (successful, n=12 and unsuccessful gymnasts, n=21)

	successful mean ± SD	**unsuccessful mean ± SD**
IF1 layout (kg/m^2)	3.79 ± 0.72	3.42 ± 0.61
IF1 pike (kg/m^2)	1.44 ± 0.26	1.28 ± 0.23
IF1 tuck (kg/m^2)	1.13 ± 0.19	1.00 ± 0.19
IF3 wide arms (kg/m^2)	0.49 ± 0.090	0.45 ± 0.081
IF3 straight (kg/m^2)	0.14 ± 0.025	0.12 ± 0.023
IF1 pike as % layout (%)	38.25 ± 1.09	37.48 ± 1.04
IF1 tuck as % layout (%)	29.93 ± 1.89	29.14 ± 1.11
IF3 straight as % wide arm (%)	28.26 ± 1.86	27.16 ± 1.69

Isometric strength variables (successful, n=12 and unsuccessful gymnasts, n=21)

	successful mean ± SD	**unsuccessful mean ± SD**
HXT ARFD (N/s)	1788 ± 1014	1780 ± 935
HXT MRFD (N/s)	2393 ± 1160	2369 ± 948
HXT NMIF (N/kg)	11.66 ± 3.63	10.12 ± 2.88
HXT NRFD (N/s)/(N/kg)	7.30 ± 2.35	9.04 ± 1.80
SEL ARFD (N/s)	1219 ± 715	883 ± 344
SEL MRFD (N/s)	2166 ± 728	1752 ± 658
SEL NMIF (N/kg)	13.87 ± 3.90	14.24 ± 4.02
SEL NRFD (N/s)/(N/kg)	5.60 ± 1.04	4.91 ± 1.84
SFX ARFD (N/s)	380 ± 196	236 ± 104
SFX MRFD (N/s)	551 ± 216	447 ± 176
SFX NMIF (N/kg)	3.29 ± 0.71	3.26 ± 0.59
SFX NRFD (N/s)/(N/kg)	5.77 ± 1.03	5.32 ± 1.71

Muscular power (jump) variables (successful, n=12 and unsuccessful gymnasts, n=21)

	successful mean ± SD	**unsuccessful mean ± SD**
DJ compression time (s)	0.126 ± 0.042	0.100 ± 0.050
DJ force pre take off (N)	1233 ± 318	1429 ± 521
DJ jump height (m)	0.213 ± 0.042	0.187 ± 0.046
DJ normalised mean POF (N/kg)	24.76 ± 3.13	26.50 ± 4.29
DJ NMPP (Nm/kgs)	31.68 ± 5.96	31.85 ± 6.94
DJ NPPP (Nm/kgs)	53.37 ± 9.00	55.47 ± 12.53
DJ PFdt (s)	0.170 ± 0.09.	0.152 ± 0.079
DJ peak jump height (m)	0.357 ± 0.071	0.314 ± 0.072
DJ push-off impulse (Ns)	56.20 ± 9.56	50.18 ± 9.14
DJ push-off time (s)	0.137 ± 0.032	0.123 ± 0.037
DJ ratio impulse (%)	118.0 ± 29.7	108.7 ± 18.0
DJ stretch height (m)	0.144 ± 0.068	0.127 ± 0.063
Standing broad jump (m)	183.3 ± 21.1	173.6 ± 13.5
Normalised standing broad jump (%)	139.2 ± 13.2	134.3 ± 9.80
VJ compression time (s)	0.506 ± 0.116	0.506 ± 0.132
VJ jump height (m)	0.296 ± 0.050	0.267 ± 0.035
VJ normalised mean POF (N)	19.84 ± 4.13	20.00 ± 3.36
VJ NMPP (Nm/kgs)	23.99 ± 11.02	22.70 ± 8.40
VJ NPPP (Nm/kgs)	56.67 ± 6.28	50.94 ± 4.88
VJ PFdt (s)	0.106 ± 0.006	0.114 ± 0.015
VJ peak jump height (m)	0.417 ± 0.51	0.378 ± 0.044
VJ peak force (N)	622 ± 128	541 ± 136
VJ push-off impulse (Ns)	63.60 ± 8.90	56.86 ± 7.52
VJ push-off time (s)	0.276 ± 0.134	0.247 ± 0.111
VJ ratio impulse (%)	252.8 ± 49.3	275.1 ± 69.2
VJ stretch height (m)	0.121 ± 0.034	0.110 ± 0.023

Flexibility variables (successful, n=12 and unsuccessful gymnasts, n=21)

Joint angle (°)	**successful mean ± SD**	**unsuccessful mean ± SD**
CSER	208.2 ± 15.4	219.0 ± 13.9
CWXT	91.8 ± 7.8	87.5 ± 10.1
BOX SPLITS	172.4 ± 6.8	164.0 ± 13.9
FAPF	156.8 ± 8.6	156.9 ± 5.5
FBKAV	226.6 ± 6.1	221.4 ± 10.5
FBRG	94.5 ± 9.9	90.4 ± 14.0
FD1	97.1 ± 4.5	87.3 ± 10.7
FFFD	122.5 ± 5.0	119.8 ± 8.9
FFRAV	123.8 ± 15.3	117.6 ± 15.8
FHSAV	157.0 ± 10.5	147.8 ± 13.8
FSDAV	100.6 ± 14.1	93.3 ± 13.1
FSFD	162.7 ± 9.5	161.9 ± 10.0
FSFX	201.4 ± 15.5	200.1 ± 11.6
FSJAV	164.7 ± 8.7	144.0 ± 17.6
FSXT	89.4 ± 8.3	86.0 ± 17.0
FWFX	101.4 ± 26.2	107.0 ± 6.4

Local Muscular Endurance variables (successful, n=12 and unsuccessful gymnasts, n=21)

Number of repetitions (n)	**successful mean ± SD**	**unsuccessful mean ± SD**
Back-ups 10 s	7.33 ± 0.98	7.10 ± 0.94
Back-ups 30 s	19.75 ± 2.70	19.19 ± 2.50
Back-ups 60 s	35.08 ± 6.93	32.71 ± 6.39
Leg dips 10 s average L& R	6.21 ± 0.87	5.24 ± 1.26
Leg dips 30 s average L& R	16.63 ± 2.60	13.12 ± 3.36
Leg dips 60 s average L& R	26.67 ± 4.41	22.74 ± 6.23
Leg lifts 10 s	5.17 ± 0.39	5.10 ± 0.30
Leg lifts 30 s	13.58 ± 1.24	12.43 ± 1.40
Leg lifts 60 s	23.00 ± 2.34	19.81 ± 3.76
Reverse leg lifts 10 s	8.33 ± 1.23	7.38 ± 1.20
Reverse leg lifts 30 s	23.08 ± 4.83	20.52 ± 4.17
Reverse leg lifts 60 s	42.92 ± 10.46	39.05 ± 7.93
Straddle lever to handstand	5.67 ± 3.08	2.90 ± 2.30

Anthropometric variables (gymnasts, n=33 and controls, n=15)

	gymnasts mean ± SD	**controls mean ± SD**
height (m)	1.300 ± 0.054	1.387 ± 0.083
sitting height (m)	0.684 ± 0.029	0.738 ± 0.052
sitting height to stature ratio (%)	52.62 ± 0.93	53.16 ± 0.88
mass (kg)	26.66 ± 2.83	33.99 ± 7.50
BMI (kg/m^2)	15.72 ± 0.83	17.50 ± 2.49
upper leg length (cm)	34.0 ± 1.9	35.8 ± 2.3
lower leg length (cm)	28.5 ± 1.8	30.0 ± 1.8
foot length (cm)	20.3 ± 1.0	21.7 ± 1.3
upper arm length (cm)	24.7 ± 1.3	26.1 ± 1.5
lower arm length (cm)	17.6 ± 1.1	19.3 ± 1.2
hand length (cm)	15.0 ± 0.8	15.5 ± 0.9
biacromial width (cm)	28.6 ± 1.8	30.0 ± 2.3
biiliac width (cm)	19.9 ± 0.9	22.0 ± 1.9
biacromial to biiliac ratio (%)	143.8 ± 6.1	136.4 ± 5.5
armspan (m)	1.323 ± 0.068	1.388 ± 0.085
armspan to stature ratio (%)	101.7 ± 1.9	100.1 ± 2.1
wrist width (cm)	4.5 ± 0.2	4.7 ± 0.3
knee width (cm)	7.6 ± 0.3	8.2 ± 0.6
ankle width (cm)	5.8 ± 0.3	6.1 ± 0.4
elbow width (cm)	5.3 ± 0.3	5.5 ± 0.4

Moment of inertia variables (gymnasts, n=33 and controls, n=15)

	successful mean ± SD	**unsuccessful mean ± SD**
IF1 layout (kg/m^2)	3.55 ± 0.67	4.88 ± 1.47
IF1 pike (kg/m^2)	1.34 ± 0.25	1.89 ± 0.57
IF1 tuck (kg/m^2)	1.04 ± 0.20	1.38 ± 0.41
IF3 wide arms (kg/m^2)	0.46 ± 0.09	0.61 ± 0.20
IF3 straight (kg/m^2)	0.13 ± 0.02	0.19 ± 0.09
IF1 pike as % layout (%)	37.76 ± 1.11	38.76 ± 0.58
IF1 tuck as % layout (%)	29.43 ± 1.46	28.33 ± 1.46
IF3 straight as % wide arm (%)	27.56 ± 1.81	31.41 ± 3.30

Isometric strength variables (gymnasts, n=33 and controls, n=15)

	successful mean ± SD	**unsuccessful mean ± SD**
HXT ARFD (N/s)	1782 ± 948	724 ± 744
HXT MRFD (N/s)	2377 ± 1012	1131± 840
HXT NMIF (N/kg)	10.68 ± 3.21	5.49 ± 1.75
HXT NRFD (N/s)/(N/kg)	8.41 ± 2.15	6.04 ± 2.78
SEL ARFD (N/s)	1005 ± 526	743 ± 341
SEL MRFD (N/s)	1903 ± 703	1172 ± 493
SEL NMIF (N/kg)	14.10 ± 3.92	8.62 ± 1.88
SEL NRFD (N/s)	5.16 ± 1.62	4.09 ± 1.51
SFX ARFD (N/s)	288 ± 158	196 ± 122
SFX MRFD (N/s)	485 ± 195	348 ± 107
SFX NMIF (N/kg)	3.27 ± 0.63	2.50 ± 0.49
SFX NRFD (N/s)/(N/kg)	5.48 ± 1.49	4.16 ± 0.99

Muscular power (jump) variables (gymnasts, n=33 and controls, n=15)

	successful mean ± SD	**unsuccessful Mean ± SD**
DJ compression time (s)	0.109 ± 0.048	0.124 ± 0.043
DJ force pre take off (N)	1358 ± 462	1488 ± 436
DJ jump height (m)	0.196 ± 0.046	0.157 ± 0.027
DJ normalised mean POF (N/kg)	25.86 ± 3.95	22.00 ± 2.68
DJ NMPP (Nm/kgs)	31.79 ± 6.50	24.11 ± 3.77
DJ NPPP (Nm/kgs)	54.71 ± 11.27	39.60 ± 6.87
DJ PFdt (s)	0.158 ± 0.082	0.223 ± 0.097
DJ peak jump height (m)	0.330 ± 0.073	0.255 ± 0.038
DJ push-off impulse (Ns)	52.37 ± 9.60	59.73 ± 14.95
DJ push-off time (s)	0.128 ± 0.035	0.151 ± 0.040
DJ ratio impulse (%)	112.1 ± 22.9	96.8 ± 11.0
DJ stretch height (m)	0.133 ± 0.064	0.098 ± 0.028
Standing broad jump (m)	177.7 ± 17.0	148.1 ± 14.9
Normalised standing broad jump (%)	136.1 ± 10.3	106.9 ± 9.5
VJ compression time (s)	0.506 ± 0.125	0.442 ± 0.079
VJ jump height (m)	0.278 ± 0.043	0.188 ± 0.029
VJ normalised mean POF (N)	19.94 ± 3.60	18.91 ± 1.89
VJ NMPP (Nm/kgs)	23.17 ± 9.29	20.38 ± 4.90
VJ NPPP (Nm/kgs)	53.02 ± 6.02	36.24 ± 4.14
VJ PFdt (s)	0.112 ± 0.013	0.152 ± 0.028
VJ peak jump height (m)	0.392 ± 0.050	0.314 ± 0.042
VJ peak force (N)	570 ± 153	542 ± 104
VJ push-off impulse (Ns)	59.31 ± 8.57	62.23 ± 18.78
VJ push-off time (s)	0.257 ± 0.119	0.211 ± 0.067
VJ ratio impulse (%)	267.0 ± 62.8	227.6 ± 39.7
VJ stretch height (m)	0.114 ± 0.027	0.126 ± 0.027

Flexibility variables (gymnasts, n=33 and controls, n=15)

Joint angle (°)	**successful mean ± SD**	**unsuccessful mean ± SD**
CSER	215.1±15.2	210.9±19.3
CWXT	89.0±9.4	83.1±9.8
FAPF	156.8±6.6	156.6±5.8
FBKAV	223.3±9.4	202.4±4.9
FD1	90.9±10.1	80.1±12.6
FFFD	120.8±7.7	86.0±12.5
FFRAV	119.9±15.7	68.1±10.2
FSFD	162.2±9.7	93.0±11.6
FSFX	200.6±13.0	188.0±10.2
FSXT	87.2±14.4	71.7±12.0
FWFX	105.0±16.4	106.2±7.0

APPENDIX 6

APPENDIX 6.1: Descriptive data for perceptual-motor talent characteristics

Appendix 6.1

Perceptual motor characteristics (all gymnasts, n=33)

	mean ± SD	min	max
Nelson balance test (s)	72.15 ± 11.43	54.04	102.61
average reaction time (s)	0.296 ± 0.074	0.170	0.444
matching with photo (°)	4.4 ± 4.2	0.5	17.5
matching 30 s delay (°)	4.2 ± 3.6	0.5	15.5
matching 180 s delay (°)	4.9 ± 4.0	0.5	16.5
pointing accuracy (cm)	10.0 ± 5.9	3.1	22.1
pointing consistency (cm)	3.5 ± 1.8	0.4	7.8
force perception (cm)	11.8 ± 14.6	0.8	76.5
rotation accuracy (°)	20.4 ± 13.3	2.9	54.6
timing accuracy (°)	6.0 ± 2.2	3.3	13.3
timing consistency (°)	5.6 ± 2.0	3.1	13.2

Sway characteristics DO stance (all gymnasts, n=33)

	mean ± SD	min	max
DO SD ax (mm)	4.25 ± 2.05	1.00	11.10
DO SD ay (mm)	5.01 ± 3.80	2.30	24.20
DO area (mm^2)	308.38 ± 459.19	42.80	2714.8
DO path (mm)	338.46 ± 110.46	152.30	615.40
DO max power (a_x) (m^2)	2.77 ± 2.03	0.45	8.15
DO frequency of max power (a_x) (Hz)	0.226 ± 0.175	0.10	0.75
DO freq 95 (a_x) (Hz)	1.19 ± 0.346	0.40	1.95
DO freq 99 (a_x) (Hz)	2.10 ± 0.439	1.35	3.05
DO signal energy (a_x) (m^2)	9.95 ± 6.55	2.19	32.80
DO max power (a_y) (m^2)	2.93 ± 3.31	0.45	8.15
DO frequency of max power (a_y) (Hz)	0.165 ± 0.108	0.10	0.75
DO freq 95 (a_y) (Hz)	1.41 ± 0.458	0.40	1.95
DO freq 99 (a_y) (Hz)	2.64 ± 0.819	1.35	3.05
DO signal energy (a_y) (mm^2)	9.54 ± 7.68	2.39	33.35
DO resultant signal energy (mm^2)	14.31 ± 9.31	3.82	40.32

Sway characteristics DC stance (all gymnasts, n=33)

	mean ± SD	**min**	**max**
DC SD ax (mm)	5.97 ± 2.99	2.30	15.70
DC SD ay (mm)	5.97 ± 2.33	2.30	14.10
DC area (mm^2)	468.66 ± 379.32	105.70	1492.2
DC path (mm)	441.97 ± 175.43	191.20	985.10
DC max power (a_x) (mm^2)	5.48 ± 6.58	0.50	31.83
DC frequency of max power (a_x) (Hz)	0.191 ± 0.131	0.100	0.600
DC freq 95 (a_x) (Hz)	1.20 ± 0.51	0.400	2.30
DC freq 99 (a_x) (Hz)	2.30 ± 0.679	1.25	3.80
DC signal energy (a_x) (mm^2)	20.10 ± 27.05	3.49	147.86
DC max power (a_y) (mm^2)	5.48 ± 6.58	0.740	36.42
DC frequency of max power (a_y)	0.17 ± 0.119	0.100	0.550
DC freq 95 (a_y) (Hz)	1.23 ± 0.382	0.550	2.25
DC freq 99 (a_y) (Hz)	2.38 ± 0.539	1.35	3.55
DC signal energy (a_y) (mm^2)	17.98 ± 17.59	4.43	63.75
DC resultant signal energy (mm^2)	28.66 ± 30.72	6.44	160.00

Sway characteristics SO stance (all gymnasts, n=33)

	mean ± SD	min	max
SO SD ax (mm)	6.25 ± 2.72	2.10	15.70
SO SD ay (mm)	6.53 ± 2.10	3.30	10.70
SO area (mm^2)	537.53 ± 351.29	93.20	1492.2
SO path (mm)	923.74 ± 454.89	341.00	2040.6
SO max power (a_x) (mm^2)	5.18 ± 3.57	1.31	23.53
SO frequency of max power (a_x)	0.326 ± 0.340	0.100	1.31
SO freq 95 (a_x) (Hz)	2.70 ± 0.504	1.75	4.10
SO freq 99 (a_x) (Hz)	3.91 ± 0.71	2.80	6.20
SO signal energy (a_x) (mm^2)	27.53 ± 11.86	11.34	59.42
SO max power (a_y) (mm^2)	6.41 ± 5.39	1.31	23.53
SO frequency of max power (a_y)	0.277 ± 0.279	0.100	1.05
SO freq 95 (a_y) (Hz)	2.36 ± 0.638	1.05	3.85
SO freq 99 (a_y) (Hz)	4.34 ± 1.13	2.40	7.50
SO signal energy (a_y) (mm^2)	29.73 ± 16.99	11.66	86.97
SO resultant signal energy (mm^2)	41.70 ± 18.18	18.53	105.33

Perceptual motor characteristics (successful, n=12 and unsuccessful gymnasts, n=21)

	successful (mean ± SD)	**unsuccessful (mean ± SD)**
Nelson balance test (s)	66.77 ± 9.33	75.22 ± 11.57
average reaction time (s)	0.285 ± 0.072	0.302 ± 0.076
matching with photo (°)	3.7 ± 2.9	4.9 ± 4.8
matching 30 s delay (°)	4.1 ± 4.1	4.3 ± 3.4
matching 180 s delay (°)	6.5 ± 3.8	4.1 ± 4.0
pointing accuracy (cm)	14.2 ± 6.9	7.6 ± 3.6
pointing consistency (cm)	3.1 ± 1.3	3.7 ± 2.1
force perception (cm)	7.0 ± 7.2	14.6 ± 17.0
rotation accuracy (°)	20.2 ± 11.9	20.4 ± 14.4
timing accuracy (°)	4.9 ± 1.0	6.6 ± 2.5
timing consistency (°)	4.7 ± 1.1	6.1 ± 2.3

Sway characteristics (DO stance) (successful, n=12 and unsuccessful gymnasts, n=21)

	successful (mean ± SD)	**unsuccessful (mean ± SD)**
DO SD ax (mm)	4.20 ± 1.44	4.29 ± 2.36
DO SD ay (mm)	4.52 ± 1.81	5.30 ± 4.59
DO area (mm^2)	242.4 ± 136.9	346.1 ± 568.3
DO path (mm)	316.6 ± 80.51	351.0 ± 124.5
DO max power (a_x) (mm^2)	2.22 ± 1.45	3.08 ± 2.27
DO frequency of max power (a_x) (Hz)	0.180 ± 0.190	0.250 ± 0.170
DO freq 95 (a_x) (Hz)	1.29 ± 0.38	1.13 ± 0.320
DO freq 99 (a_x) (Hz)	2.26 ± 0.440	2.02 ± 0.430
DO signal energy (a_x)	8.13 ± 4.01	10.99 ± 7.53
DO max power (a_y)	2.26 ± 2.04	3.31 ± 3.85
DO frequency of max power (a_y) (Hz)	0.163 ± 0.121	0.167 ± 0.103
DO freq 95 (a_y) (Hz)	1.27 ± 0.300	1.48 ± 0.520
DO freq 99 (a_y) (Hz)	2.55 ± 0.810	2.69 ± 0.840
DO signal energy (a_y)	8.40 ± 6.26	10.20 ± 8.46
DO resultant signal energy	12.13 ± 6.62	15.55 ± 10.49

Sway characteristics (DC stance) (successful, n=12 and unsuccessful gymnasts, n=21)

	successful (mean ± SD)	**unsuccessful (mean ± SD)**
DC SD ax (mm)	6.65 ± 3.57	5.59 ± 2.62
DC SD ay (mm)	5.69 ± 1.82	6.12 0 ± 2.60
DC area (mm^2)	507.7 ± 412.9	446.3 ± 367.5
DC path (mm)	450.1 ± 191.1	437.3 ± 170.5
DC max power (a_x) (mm^2)	2.93 ± 3.33	6.93 ± 7.55
DC frequency of max power (a_x) (Hz)	0.220 ± 0.160	0.170 ± 0.110
DC freq 95 (a_x) (Hz)	1.42 ± 0.43	1.08 ± 0.52
DC freq 99 (a_x) (Hz)	2.59 ± 0.64	2.13 ± 0.65
DC signal energy (a_x) (mm^2)	10.57 ± 8.34	25.55 ± 32.36
DC max power (a_y) (mm^2)	4.53 ± 7.80	7.01 ± 8.62
DC frequency of max power (a_y) (Hz)	0.163 ± 0.088	0.181 ± 0.136
DC freq 95 (a_y) (Hz)	1.13 ± 0.320	1.28 ± 0.41
DC freq 99 (a_y) (Hz)	2.47 ± 0.450	2.33 ± 0.590
DC signal energy (a_y) (mm^2)	14.47 ± 15.99	19.98 ± 18.51
DC resultant signal energy (mm^2)	18.41 ± 17.48	34.52 ± 35.25

Sway characteristics (SO stance) (successful, n=12 and unsuccessful gymnasts, n=21)

	successful (mean ± SD)	**unsuccessful (mean ± SD)**
SO SD ax (mm)	6.43 ± 3.67	6.16 ± 2.09
SO SD ay (mm)	5.93 ± 1.93	6.87 ± 2.15
SO area (mm^2)	506.9 ± 412.9	555.0 ± 320.6
SO path (mm)	554.3 ± 255.1	1134.9 ± 408.1
SO max power (a_x) (mm^2)	4.80 ± 3.89	5.41 ± 3.45
SO frequency of max power (a_x)	0.240 ± 0.240	0.380 ± 0.380
SO freq 95 (a_x) (Hz)	2.45 ± 0.370	2.84 ± 0.520
SO freq 99 (a_x) (Hz)	3.72 ± 0.510	4.03 ± 0.800
SO signal energy (a_x) (mm^2)	22.01 ± 6.40	30.69 ± 13.19
SO max power (a_y) (mm^2)	5.78 ± 6.56	6.77 ± 4.74
SO frequency of max power (a_y)	0.238 ± 0.168	0.300 ± 0.327
SO freq 95 (a_y) (Hz)	2.13 ± 0.590	2.49 ± 0.640
SO freq 99 (a_y) (Hz)	4.03 ± 0.900	4.52 ± 1.23
SO signal energy (a_y) (mm^2)	27.84 ± 14.03	30.80 ± 18.72
SO resultant signal energy (mm^2)	36.04 ± 13.96	44.94 ± 19.78

Perceptual motor characteristics (gymnasts, n=33 and controls, n=15)

	gymnasts (mean ± SD)	**controls (mean ± SD)**
Nelson balance test (s)	72.15 ± 11.43	99.36 ± 32.95
average reaction time (s)	0.296 ± 0.074	0.318 ± 0.092
matching with photo (°)	4.4 ± 4.2	7.4 ± 1.8
matching 30 s delay (°)	4.2 ± 3.6	6.2 ± 4.1
matching 180 s delay (°)	4.9 ± 4.0	8.7 ± 6.9
rotation accuracy (°)	20.4 ± 13.3	21.8 ± 11.7
timing accuracy (°)	6.0 ± 2.2	10.8 ± 4.8
timing consistency (°)	5.6 ± 2.0	10.1 ± 4.4

APPENDIX 7

APPENDIX 7.1: Gymnast TEOSQ

APPENDIX 7.2: 'Parentised' TEOSQ

APPENDIX 7.3: 'Coachised' TEOSQ

APPENDIX 7.4: Self Perception Profile for Children (Harter, 1985)

Appendix 7.1

DIRECTIONS

Please read each of the statements listed below and indicate how much you personally agree with each statement by circling the appropriate response.

When do you feel most successful in gymnastics? In other words when do you feel gymnastics has gone really well for you?

I feel most successful in gymnastics when .....

A Strongly disagree	B disagree	C neither agree nor disagree	D agree	E Strongly agree

1.	I'm the only one who can do a move	A	B	C	D	E
2.	I learn a new move and it makes me want to practice more	A	B	C	D	E
3.	I can do better than my friends	A	B	C	D	E
4.	The others can't do as well as me	A	B	C	D	E
5.	I learn something new that is fun to do	A	B	C	D	E
6.	Others mess up and I don't	A	B	C	D	E
7.	I learn a new move by trying hard	A	B	C	D	E
8.	I work really hard	A	B	C	D	E
9.	I score the highest mark	A	B	C	D	E
10.	Something I learn makes me want to go and practice more	A	B	C	D	E
11.	I'm the best	A	B	C	D	E
12.	A move I learn really feels right	A	B	C	D	E
13.	I do my very best	A	B	C	D	E

Appendix 7.2

Name ..... Name of daughter ..... Resp no. .....

DIRECTIONS

Please read each of the statements listed below and indicate how much you personally agree with each statement by circling the appropriate response.

When do you feel that your daughter is most successful in gymnastics? In other words when do you feel gymnastics has gone really well for her?

I feel that my daughter is most successful in gymnastics when .....

		A Strongly disagree	B disagree	C neither agree nor disagree	D agree	E Strongly agree
1.	She is the only one who can do a move	A	B	C	D	E
2.	She learns a new move and it makes her want to practice more	A	B	C	D	E
3.	She can do better than her friends	A	B	C	D	E
4.	The others can't do as well as her	A	B	C	D	E
5.	She learns something new that is fun to do	A	B	C	D	E
6.	Others mess up and she doesn't	A	B	C	D	E
7.	She learns a new move by trying hard	A	B	C	D	E
8.	She works really hard	A	B	C	D	E
9.	She scores the highest mark	A	B	C	D	E
10.	Something she learns makes her want to go and practice more	A	B	C	D	E
11.	She's the best	A	B	C	D	E
12.	A move she learns really feels right	A	B	C	D	E
13.	She does her very best	A	B	C	D	E

Appendix 7.3

Name ..... Name of club .....

DIRECTIONS

Please read each of the statements listed below and indicate how much you personally agree with each statement by circling the appropriate response.

When do you feel that a gymnast is most successful in gymnastics? In other words when do you feel gymnastics has gone really well for one of your gymnasts?

I feel that a gymnast is most successful in gymnastics when .....

A	B	C	D	E
Strongly disagree	**disagree**	**neither agree nor disagree**	**agree**	**Strongly agree**

1.	She is the only one who can do a move	A	B	C	D	E
2.	She learns a new move and it makes her want to practice more	A	B	C	D	E
3.	She can do better than her friends	A	B	C	D	E
4.	The others can't do as well as her	A	B	C	D	E
5.	She learns something new that is fun to do	A	B	C	D	E
6.	Others mess up and she doesn't	A	B	C	D	E
7.	She learns a new move by trying hard	A	B	C	D	E
8.	She works really hard	A	B	C	D	E
9.	She scores the highest mark	A	B	C	D	E
10.	Something she learns makes her want to go and practice more	A	B	C	D	E
11.	She's the best	A	B	C	D	E
12.	A move she learns really feels right	A	B	C	D	E
13.	She does her very best	A	B	C	D	E

What I Am Like

Name ..... Age ..... Date of birth .....

SAMPLE SENTENCE

	Really True for me	Sort of True for me				Sort of True for me	Really True for me
(a)	☐	☐	Some kids would rather play outdoors in their spare time	**BUT**	Other kids would rather watch T.V.	☐	☐
1.	☐	☐	Some kids feel that they are very *good* at their school work	**BUT**	Other kids *worry* about whether they can do the school work assigned to them.	☐	☐
2.	☐	☐	Some kids find it *hard* to make friends	**BUT**	Other kids find it's pretty *easy* to make friends.	☐	☐
3.	☐	☐	Some gymnasts do very *well* on all pieces of apparatus	**BUT**	Other gymnasts *don't* feel that they are very good when it comes to gymnastics.	☐	☐
4.	☐	☐	Some kids are *happy* with the way they look	**BUT**	Other kids are *not* happy with the way they look.	☐	☐
5.	☐	☐	Some kids often do *not* like the way they *behave*	**BUT**	Other kids usually *like* the way they behave.	☐	☐

6.	☐	☐	Some kids are often *unhappy* with themselves	**BUT**	Other kids are pretty *pleased* with themselves.	☐	☐
7.	☐	☐	Some kids feel like they are *just as smart* as other kids their age	**BUT**	Other kids aren't so sure and *wonder* if they are as smart.	☐	☐
8.	☐	☐	Some kids have *alot* of friends	**BUT**	Other kids *don't* have very many friends.	☐	☐
9.	☐	☐	Some kids wish they could be alot better at gymnastics	**BUT**	Other kids feel they are good enough at gymnastics.	☐	☐
10.	☐	☐	Some kids are *happy* with their height and weight	**BUT**	Other kids wish their height or weight were *different.*	☐	☐
11.	☐	☐	Some kids usually do the *right* thing	**BUT**	Other kids often *don't* do the right thing.	☐	☐
12.	☐	☐	Some kids *don't* like the way they are leading their life	**BUT**	Other kids *do* like the way they are leading their life.	☐	☐
13.	☐	☐	Some kids are pretty *slow* in finishing their school work	**BUT**	Other kids can do their school work *quickly.*	☐	☐
14.	☐	☐	Some kids would like to have alot more friends	**BUT**	Other kids may have as many friends as they want.	☐	☐
15.	☐	☐	Some gymnasts think they could do well at just about any new move they haven't tried before	**BUT**	Other gymnasts are afraid they might *not do* well at moves they haven't ever tried.	☐	☐
16.	☐	☐	Some kids wish their body was *different*	**BUT**	Other kids *like* their body the way it is.	☐	☐

17.	☐	☐	Some kids usually *act* the way they know they are *supposed* to	**BUT**	Other kids often *don't* act the way they are supposed to.	☐	☐
18.	☐	☐	Some kids are *happy* with themselves as a person	**BUT**	Other kids are often *not* happy with themselves.	☐	☐
19.	☐	☐	Some kids often *forget* what they learn	**BUT**	Other kids can remember things *easily.*	☐	☐
20.	☐	☐	Some kids are always doing things with *alot* of kids	**BUT**	Other kids usually do things *by themselves.*	☐	☐
21.	☐	☐	Some kids feel that they are *better* than others their age at gymnastics	**BUT**	Other kids *don't* feel they are as good.	☐	☐
22.	☐	☐	Some kids wish their physical appearance (how they look) was *different*	**BUT**	Other kids *like* their physical appearance the way it is.	☐	☐
23.	☐	☐	Some kids usually get in *trouble* because of things they do	**BUT**	Other kids usually *don't* do things that get them in trouble.	☐	☐
24.	☐	☐	Some kids *like* the kind of *person* they are	**BUT**	Other kids often wish they were someone else.	☐	☐
25.	☐	☐	Some kids do *very well* at their classwork	**BUT**	Other kids *don't* do very well at their classwork.	☐	☐
26.	☐	☐	Some kids wish that more people their age liked them	**BUT**	Other kids feel that most people their age *do* like them.	☐	☐

27.	☐	☐	In gymnastics some kids usually *watch* instead of taking part	**BUT**	Other kids usually *take part* rather than watch.	☐	☐
28.	☐	☐	Some kids wish something about their face or hair looked *different*	**BUT**	Other kids *like* their face and hair the way they are.	☐	☐
29.	☐	☐	Some kids do things they know they *shouldn't* do	**BUT**	Other kids *hardly ever* do things they know they shouldn't do.	☐	☐
30	☐	☐	Some kids are very *happy* being the way they are	**BUT**	Other kids wish they were *different.*	☐	☐
31.	☐	☐	Some kids have *trouble* figuring out the answers in school	**BUT**	Other kids almost *always* can figure out the answers.	☐	☐
32.	☐	☐	Some kids are *popular* with others their age	**BUT**	other kids are *not* very popular.	☐	☐
33.	☐	☐	Some gymnasts *don't* do well at new moves	**BUT**	Other gymnasts are *good* at new moves right away.	☐	☐
34.	☐	☐	Some kids think that they are good looking	**BUT**	Other kids think that they are not very good looking.	☐	☐
35.	☐	☐	Some kids behave themselves very well	**BUT**	Other kids often find it hard to behave themselves.	☐	☐
36.	☐	☐	Some kids *are* not very happy with the way they do alot of things	**BUT**	Other kids think the way they do things is *fine.*	☐	☐

Identification and Systematic Selection of Gymnastic Talent

March 1994

This questionnaire aims to generate information regarding the identification and systematic selection of talent for

Women's Artistic Gymnastics

in the Country of _____

CONFIDENTIALITY

The information sought through this questionnaire is to be used for research purposes. All the data will be treated in confidence and in accordance with the Data Protection Act currently in force in Great Britain. All respondents will be sent a copy of the computer record of their own contribution upon request. Please mark any questions which you are unable to answer with a dash to indicate that they have not been omitted by accident.

British Amateur Gymnastics Association/Loughborough University of Technology/Sports Council TI_294

Section 1 – Historical Development

1. When was a systematic process of selection first established in this Country?

---

2. For what reason(s) was the original systematic process established?

Please tick box(es)

In response to a specific stimulus	
A natural progression	
Other	

Please give details

---

3. Who founded the original systematic process?

A single individual	
An organisation	
Other	

Please give details

---

4. Who was responsible for the implementation of the original systematic process?

---

5. Who was responsible for the operation of the original systematic process?

---

6. Please give a brief outline of the structure of the original systematic process

---

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7. What major changes have been made to the original systematic process?

Section 2 – The Current Structure of Gymnastic Development

8. Table 1. - Please complete the table below indicating the various levels of gymnastic development in your Country.

Age of gymnasts	Venue for training	Number of venues nationally	Number of gymnasts nationally	Type of training	Number of training sessions per week	Number of hours trained per week

Any additional information regarding the structure of gymnastic development in your Country would be welcomed. Please use the continuation sheets provided at the end of the questionnaire or attach any additional material.

Section 3 – Stages of Selection

9. Table 2. - Please complete the table below indicating the organisation of the various stages of the systematic selection process.

Selection stage	Age of gymnasts	Selector	Venue gymnasts are selected from	Venue gymnasts are directed to	Selection venue	Number of gymnasts selected	Quotas of gymnasts to be selected

Please briefly describe the selection stages you have listed in the space provided overleaf. Then retain these stages for use in all subsequent tables.

10. Please briefly describe the stages of selection you have listed overleaf

---

---

11. Who is currently responsible for the organisation of the systematic selection process?

---

12. Who is currently responsible for funding of the systematic selection process?

---

13. Are there specific quotas of gymnasts that must be selected to enter each level of gymnastic development?

YES	
NO	

If no, please go to question 15.

If yes, please indicate quota numbers in Table 2 for the various stages of selection

14. How are these quotas determined?

---

15. Are the numbers of gymnasts selected at each stage modified according to the abilities of the children in the talent pool?

YES	
NO	

Section 4 – Design of the Systematic Selection Process

16. Indicate which of the following categories of variables are included in each stage of the systematic selection process and rate their importance at each stage according to the following scale:

1 = unimportant 2 = not very important 3 = important 4 = very important 5 = essential

Categories of Variables	Stages of Selection [•1]							
Anthropometric								
Other Physical								
Physiological								
Psychological								
Psycho-social								
Situational								
Organic								
Motor								
Perceptual-motor								
Genetic								
Biochemical								
Medical								
Others (please list)								

[•1] Refer to Table 2 for stages of selection

17. Who designs the systematic selection process?

---

18. How are the categories of variables used in the systematic selection process decided upon?

---

19. Which methods are used in the design of the systematic selection process?

Please tick box(es)

Analysis of elite international gymnasts	
Analysis of elite national gymnasts	
Subjective task analysis	
Analysis of individual measured variables	
Other (please specify)	

Section 5 – Review and Modification

20. Is the development programme for gymnastics modified for any reason?

YES	
NO	

If no, please go to question 26.

21. For what reasons would modifications be made to the development programme?

Please tick box(es)

To account for changes in the nature if elite international gymnasts	
To account for changes/developments in the sport	
The result of a regular review process	
Other, please specify	

---

22. Does the modification/review of the process follow a regular temporal pattern?

YES	
NO	

23. How often is this review and any subsequent modification conducted?

Monthly	
Annually	
Cyclically, please specify	
Other, please specify	

---

24. Does this modification affect all levels of gymnastic development?

YES	
NO	

25. Please specify the degree of influence the modification has on each stage of the systematic selection process.

Stage of selection [•1]	Influence rating [•2]

26. Who is responsible for deciding the long-term gymnastic prognosis?

---

27. How does this prognosis influence the systematic selection process?

[•1] Refer to Table 2 for stages of selection

[•2] Rate the influence of the review process according to the following scale:

1=no influence 2=not very influential 3=moderately influential 4=very influential 5=extremely influential

Section 6 – Profiling

(a) Anthropometric/Physical Profiling

28. By completing the table below, indicate which anthropometric/physical parameters are evaluated in each stage of the systematic selection process. Rate the importance of each parameter in relation to the other anthropometric parameters in the same stage of selection.

Stage of Selection [•1]	Anthropometric/Physical Parameters [•2]	Rating of Importance [•3]

Stage of Selection •1	Anthropometric/Physical Parameters •2	Rating of Importance •3

30. How are the norms (ideals) for these anthropometric parameters derived?

Please tick box(es)

Studies of elite international gymnasts	
Studies of elite national gymnasts	
Theoretical predictions	
Other, please specify	

---

31. Is the child's maturity status evaluated during the systematic selection process?

YES	
NO	

If no, go to question 34.

32. At what stage(s) of the systematic selection process does the evaluation of maturity status occur?

---

33. Which indicators of maturity are used in the evaluation of the child's maturity status?

---

34. Is the child's future maturity status predicted at any time during the systematic selection process?

YES	
NO	

If no, please go to question 37.

35. At what stage(s) of the selection process does the prediction of future maturity status occur?

---

36. Which indicators of future maturity are used in the prediction of the child's future maturity status?

---

37. Is the technique of somatotyping used in the selection process?

YES	
NO	

If no, please go to question 39.

38. What are the normative (ideal) values for endomorphy, mesomorphy and ectomorphy at the various stages of the systematic selection process?

Please attach any additional sheets to the questionnaire. Continuation sheets, if required, are provided at the end of the questionnaire.

(b) Physiological Profiling

39. By completing the table below, indicate which physiological parameters are evaluated in each stage of the systematic selection process. Rate the importance of each parameter in relation to the other physiological parameters in the same stage of selection.

Stage of Selection [•1]	Physiological Parameters [•2]	Rating of Importance [•3]	Test used to measure parameter

Stage of Selection •1	Physiological Parameters •2	Rating of Importance •3	Test used to measure parameter

41. How are the norms (ideals) for these physiological parameters derived?

Please tick box(es)

Studies of elite international gymnasts	
Studies of elite national gymnasts	
Theoretical predictions	
Other, please specify	

---

42. What is the estimated contribution of the three energy systems (aerobic, anaerobic lactic and anaerobic alactic) to overall gymnastic performance?

---

43. Do these contributions change over the course of gymnastic development?

YES	
NO	

If no, please go to question 44.

If yes, please give details

(c) Psychological Profiling

44. By completing the table below, indicate which psychological variables are evaluated in each stage of the systematic selection process. Rate the importance of each variable in relation to the other psychological variables in the same stage of selection.

Stage of Selection •1	Psychological Variable •2	Rating of Importance •3	Test used to measure variable

Stage of Selection [•1]	Psychological Variable [•2]	Rating of Importance [•3]	Test used to measure variable

46. How are the norms (ideals) for these psychological variables derived?

Please tick box(es)

Studies of elite international gymnasts	
Studies of elite national gymnasts	
Theoretical predictions	
Other, please specify	

---

47. Whose responsibility is it to assess the child's psychological profile at the various stages of the systematic selection process?

(d) Psycho-social Profiling

48. Are psycho-social factors taken into consideration in the selection of gymnasts?

YES	
NO	

If yes, please complete the table overleaf

If no, please go to question 50.

49. By completing the table below, indicate which psycho-social variables are evaluated in each stage of the systematic selection process. Rate the importance of each variable in relation to the other psycho-social variables in the same stage of selection.

Stage of Selection •1	Psycho-social Variable •2	Rating of Importance •3	Index of measurement

Stage of Selection •1	Psycho-social Variable •2	Rating of Importance •3	Test used to measure variable

(e) Situational Profiling/Analysis

50. Is the child's situation[•1] evaluated and included as a criterion in the selection process?

YES	
NO	

If yes, please give details in the table overleaf

If no, please go to question 52.

[•1] Situation refers to aspects of the child's environment which may influence that child's chances of fulfilling their gymnastic potential

51. By completing the table below, indicate which situational variables are evaluated in each stage of the systematic selection process. Rate the importance of each variable in relation to the other situational variables in the same stage of selection.

Stage of Selection •1	situational Variable •2	Rating of Importance •3	Index of measurement

Stage of Selection [•1]	Situational Variable [•2]	Rating of Importance [•3]	Test used to measure variable

(f) Organic Profiling

52. Which categories of organic variables are evaluated in the systematic selection process?

Please tick box(es)

Static strength	
Dynamic strength	
Power	
Muscular endurance	
Muscular speed	
Speed	
Balance	
Coordination	
Passive flexibility	
Active flexibility	
Other(s) please specify	

---

53. By completing the table below, indicate which categories of organic variables are evaluated at each stage of the systematic selection process. Rate the importance of each category in relation to the other categories of organic variables in the same stage of selection.

Stage of Selection [•1]	Category of Organic Variable [•2]	Rating of Importance [•3]	Index of measurement
	Static strength		
	Dynamic Strength		
	Power		
	Muscular endurance		
	Muscular speed		
	Speed		
	Balance		
	Coordination		
	Passive flexibility		
	Active flexibility		
	Others (please specify)		
	Static strength		
	Dynamic Strength		
	Power		
	Muscular endurance		
	Muscular speed		
	Speed		
	Balance		
	Coordination		
	Passive flexibility		
	Active flexibility		
	Others (please specify)		

Please continue overleaf

[•1] Refer to Table 2 for stages of selection

[•2] Include all categories of organic variables

[•3] Rate the importance of each category of organic variables according to the following scale:

1=no importance 2=not very important 3=moderately important 4=very important 5=extremely important

Stage of Selection [•1]	Category of Organic Variable [•2]	Rating of Importance [•3]	Test used to measure variable
	Static strength		
	Dynamic Strength		
	Power		
	Muscular endurance		
	Muscular speed		
	Speed		
	Balance		
	Coordination		
	Passive flexibility		
	Active flexibility		
	Others (please specify)		
	Static strength		
	Dynamic Strength		
	Power		
	Muscular endurance		
	Muscular speed		
	Speed		
	Balance		
	Coordination		
	Passive flexibility		
	Active flexibility		
	Others (please specify)		

Please continue overleaf

[•1] Refer to Table 2 for stages of selection

[•2] Include all categories of organic variables

[•3] Rate the importance of each category of organic variables according to the following scale:

1=no importance 2=not very importance 3=moderately important 4=very important 5=extremely important

Stage of Selection [•1]	Category of Organic Variable [•2]	Rating of Importance [•3]	Test used to measure variable
	Static strength		
	Dynamic Strength		
	Power		
	Muscular endurance		
	Muscular speed		
	Speed		
	Balance		
	Coordination		
	Passive flexibility		
	Active flexibility		
	Others (please specify)		
	Static strength		
	Dynamic Strength		
	Power		
	Muscular endurance		
	Muscular speed		
	Speed		
	Balance		
	Coordination		
	Passive flexibility		
	Active flexibility		
	Others (please specify)		

Please continue overleaf

[•1] Refer to Table 2 for stages of selection

[•2] Include all categories of organic variable

[•3] Rate the importance of each category of organic variables according to the following scale:

1=no importance 2=not very important 3=moderately important 4=very important 5=extremely important

Stage of Selection [•1]	Organic Variable [•2]	Rating of Importance [•3]	Test used to measure variable
	Static strength		
	Dynamic Strength		
	Power		
	Muscular endurance		
	Muscular speed		
	Speed		
	Balance		
	Coordination		
	Passive flexibility		
	Active flexibility		
	Others (please specify)		
	Static strength		
	Dynamic Strength		
	Power		
	Muscular endurance		
	Muscular speed		
	Speed		
	Balance		
	Coordination		
	Passive flexibility		
	Active flexibility		
	Others (please specify)		

Please continue overleaf

[•1] Refer to Table 2 for stages of selection

[•2] Include all categories of organic variables

[•3] Rate the importance of each category of organic variables according to the following scale:

1=no importance 2=not very important 3=moderately important 4=very important 5=extremely important

54. How are the results from organic tests assessed?

Please tick box(es)

As absolute values	
Expressed as values relative to physical parameters	
Other, please specify	

---

55. What are the norms (ideals) for the organic variables evaluated in each stage of the systematic selection process?

Please attach any additional sheets to the questionnaire. Continuation sheets, if required, are provided at the end of the questionnaire.

56. How are the norms (ideals) for these organic variables derived?

Please tick box(es)

Studies of elite international gymnasts	
Studies of elite national gymnasts	
Theoretical predictions	
Other, please specify	

---

57. Are the results of these organic tests evaluated in relation to:

Maturity status	
Chronological age	
Both of the above	
Neither of the above	

58. Is the effect of prior experience, including previous training, incorporated into the interpretation of these organic test results?

YES	
NO	

If yes, please give details

---

59. Is an assessment of the rate of improvement in a child's performance in the various organic tests incorporated into the systematic selection process?

YES	
NO	

If yes, please give details

(g) Motor Profiling

60. Are certain motor skills fundamental for gymnastic success?

YES	
NO	

If no, please go to question 64

61. Which motor skills are fundamental for gymnastic success?

---

62. How are these motor skills determined to be fundamental for gymnastic success?

---

63. Which motor abilities underlie these skills?

---

64. By completing the table below, indicate which motor skills are evaluated in each stage of the systematic selection process. Rate the importance of each motor skill in relation to the other motor skills in the same stage of selection.

Stage of Selection [•1]	Motor skills [•2]	Rating of Importance [•3]	Test used in measurement

Stage of Selection [•1]	Motor skills [•2]	Rating of Importance [•3]	Test used in measurement.

65. What are the norms (ideals) for the performance of the motor skills used in each stage of the systematic selection process?

Please attach any additional sheets to the questionnaire. Continuation sheets, if required, are provided at the end of the questionnaire.

66. How are the norms (ideals) for these motor skills derived?

Please tick box(es)

Studies of elite international gymnasts	
Studies of elite national gymnasts	
Theoretical predictions	
Other, please specify	

---

67. In assessing motor skill performance in the selection process is an assessment made of the variation in performance that is attributable to genetic variation?

YES	
NO	

If yes, please give details

---

68. In assessing motor skill performance in the selection process is an assessment made of the variation in performance that is attributable to environmental influences?

YES	
NO	

If yes, please give details

---

69. Are tests used to determine or account taken of the child's motor educability?

YES	
NO	

If yes, please give details

(h) Perceptual-motor characteristics

70. Are the child's perceptual-motor characteristics evaluated in the selection process?

YES	
NO	

If yes, please give details in the table overleaf:

71. By completing the table below, indicate which perceptual-motor variables are evaluated in each stage of the systematic selection process. Rate the importance of each perceptual-motor variable in relation to the other motor skills in the same stage of selection.

Stage of Selection [•1]	Perceptual-motor variable [•2]	Rating of Importance [•3]	Test used in measurement

Stage of Selection [•1]	Perceptual-motor variable [•2]	Rating of Importance [•3]	Test used in measurement.

(i) Genetic Profiling

72. Is genetic profiling included at any stage in the systematic selection process?

YES	
NO	

If no, please go to question 78.

73. What is the role of genetic profiling in the systematic selection process?

---

74. How important is genetic profiling to the systematic selection process?

Essential	
Very important	
Important	
Not very important	
Unimportant	

75. By completing the table below, indicate which genetic parameters are evaluated in each stage of the systematic selection process. Rate the importance of each parameter in relation to the other genetic parameters in the same stage of selection.

Stage of Selection [•1]	Genetic parameters [•2]	Rating of Importance [•3]

Stage of Selection [•1]	Genetic parameters [•2]	Rating of Importance [•3]

76. Who is responsible for the genetic profiling?

---

77. Where does the genetic profiling take place?

(j) Biochemical Profiling

78. Are biochemical parameters used at any stage in the selection process?

YES	
NO	

If yes, please give details in the table overleaf:

79. By completing the table below, indicate which biochemical variables are evaluated in each stage of the systematic selection process. Rate the importance of each biochemical variable in relation to the other biochemical variables in the same stage of selection.

Stage of Selection [•1]	Biochemical variable [•2]	Rating of Importance [•3]	Test used in measurement

Stage of Selection [•1]	Biochemical variable [•2]	Rating of Importance [•3]	Test used in measurement.

(k) Medical aspects of selection

80. What role does sports medicine play in the systematic selection process?

Please give details in the table overleaf:

81. By completing the table below, indicate which medical variables are evaluated in each stage of the systematic selection process. Rate the importance of each medical variable in relation to the other medical variables in the same stage of selection.

Stage of Selection [•1]	Medical variable [•2]	Rating of Importance [•3]	Test used in measurement

Stage of Selection [•1]	Medical variable [•2]	Rating of Importance [•3]	Test used in measurement.

82. Who conducts the medical testing?

---

83. Where does the medical testing take place?

---

84. How often is the gymnast's state of health assessed?

---

85. Are medical evaluations conducted early in the systematic selection process to determine whether the child is anatomically suitable for high level gymnastic training?

YES	
NO	

If yes, please give details

---

86. At what stage(s) in the systematic selection process are medical tests/evaluations performed?

If other categories of variables are included in the systematic selection process which have not been mentioned, please give details of these variables and their corresponding norms (ideals) in the space provided at the end of the questionnaire.

Section 7 – Assessment of the selection criteria

87. Once the selection tests have been completed how are the results computed to determine which gymnasts are selected to progress to the next stage of gymnastic development?

---

88. Has an overall formula been developed at each stage of the systematic selection process to determine who is chosen to advance to the next level of training?

---

89. Are the various criteria weighted in terms of their relative importance at each stage of the systematic selection process?

YES	
NO	

If no, please go to question 91

If yes, please give details of these weightings in the tables overleaf:

90. Please give details of the weightings assigned to each category of variables incorporated in the systematic selection process. Also, please provide the weightings assigned to the individual variables within each category.

Categories/Variables	**Stages of Selection** [•1]							
Anthropometric								
Other Physical								

Continued overleaf

[•1] Refer to Table 2 for stages of selection

Categories/Variables	Stages of Selection [•1]							
Physiological								
Psychological								

Continued Overleaf

[•1] Refer to Table 2 for stages of selection

Categories/Variables	Stages of Selection [•1]							
Psycho-social								
Situational								

Continued overleaf

[•1] Refer to Table 2 for stages of selection

Categories/Variables	Stages of Selection [*1]							
Organic								
Motor								

Continued overleaf

[*1] Refer to Table 2 for stages of selection

Categories/Variables	Stages of Selection [*1]							
Perceptual-motor								
Genetic								

Continued overleaf

[*1] Refer to Table 2 for stages of selection

Categories/Variables	Stages of Selection [•1]							
Biochemical								
Medical								

Continued overleaf

[•1] Refer to Table 2 for stages of selection

Please use the table below to provide information regarding the weighting of variables in categories that are included in the overall selection formula which have not yet been mentioned:

Categories/Variables	**Stages of Selection** [•1]							

[•1] Refer to Table 2 for stages of selection

91. How are these weightings established?

---

92. Is any weighting given to the perception of the coach in terms of his/her 'gut feeling' as to whether a gymnast should/should not progress to the next developmental level?

YES	
NO	

If yes, please give details

---

93. What percentage of the selection testing is conducted in a laboratory situation and what percentage is conducted in the gym?

Selection stage	Percentage of tests (lab)	Percentage of tests (gym)

94. Does the location of the testing have a tendency to change in the later stages of the systematic selection process as the number of gymnasts decreases?

YES	
NO	

If yes, please give details

---

95. How many times are gymnasts tested at each stage of their gymnastic development?

1	
2	
3-5	
6-10	
More than 10	

96. Are the results of the testing used to modify the gymnast's training programmes for the next training cycle?

YES	
NO	

If yes, please give details

---

97. If a gymnast has specific weaknesses which are identified through the testing are the training programmes adapted accordingly?

YES	
NO	

If yes, please give details

---

98. Are training programmes modified in response to the weaknesses identified in the testing sessions?

Please tick box(es)

In addition to the normal training programme	
Incorporated into the normal training programme	

99. Is the selection process monitored and controlled via internal feedback to determine weaknesses in its organisation/make-up? (For example, is the system monitored to ensure that an adequate number of talented youngsters are selected, who are of the required standard to enter the next stage of gymnastic development?)

YES	
NO	

If yes, please give details

---

100. Is the selection process monitored and controlled to account for changes in the requirements/demands of the sport?

YES	
NO	

If yes, please give details

That is the end of the questionnaire. Thank you very much for your help.

Any further information regarding the systematic selection process will be gratefully received.

Continuation sheets for information regarding any additional categories of variables evaluated in the systematic selection process:

Stage of Selection [•1]	Variable [•2]	Rating of Importance [•3]	Test used in measurement

Stage of Selection [•1]	Variable [•2]	Rating of Importance [•3]	Test used in measurement

Stage of Selection [•1]	Variable [•2]	Rating of Importance [•3]	Test used in measurement