ANTHROPOMETRIC AND PHYSICAL PERFORMANCE CHARACTERISTICS OF TOP-ELITE, ELITE AND NON-ELITE YOUTH FEMALE TEAM HANDBALL PLAYERS

Abstract

In order to maximise the potential for success, developing nations need to produce superior systems to identify and develop talent, which requires comprehensive and up-to-date values on elite players. This study examined the anthropometric and physical characteristics of youth female team handball players (16.07 ± 1.30 y) in non-elite ($n= 47$), elite ($n= 37$) and top-elite players ($n= 29$). Anthropometric profiling included sum of eight skinfolds, body mass, stature, girths, breadths and somatotype. Performance tests included 20 m sprint, counter movement jump, throwing velocity, repeated shuttle sprint and jump ability test, and Yo-Yo Intermittent Recovery Test Level 1. Youth top-elite players had greater body mass, lean mass, stature, limb girths and breadths than elite and non-elite players, while only stature and flexed arm were higher in elite compared to non-elite players (all $P < 0.05$). Sum of skinfolds and waist-to-hip ratio were similar between groups ($P > 0.05$). Top-elite performed better in most performance tests compared to both elite and non-elite players ($P < 0.05$), although maximal and repeated 10 m sprints were similar between standard ($P > 0.05$). Elite outperformed non-elite players in throwing velocity only. Findings reveal that non-elite players compare unfavourably to top-elite international European players in many anthropometric and performance characteristics, and differ in few characteristics compared to elite European club team players. This study is useful for emerging team handball nations in improving talent identification processes.

Keywords: talent identification, testing, kinanthropometry, standard

Introduction

Team handball is an intermittent team sport, characterised by high-intensity explosive movements such as sprints, jumps, throws, and physical confrontations, which are interspersed with periods of low intensity activity such as standing, walking, and jogging (Michalsik, Aagaard, & Madsen, 2013a; Michalsik, Madsen, & Aagaard, 2014a). Success in team handball is determined by a variety of technical and tactical, mental, anthropometric, and physical performance characteristics (Vila et al., 2012). Although the measurement of technical and tactical skills are often confounded by subjectivity, assessment for anthropometric and physical profiles enable the collection of objective data, which can be used to form structured talent detection and identification programmes (Bloomfield, Ackland, & Elliot, 1994) and identify areas for training focus.

Information on the essential characteristics for successful team handball performance is valuable to coaches and practitioners working with developing nations, where there are a limited number of athletes to select from and the sport is not well established (Mohamed et al., 2009). From a relatively unknown sport in Great Britain prior to the 2012 Olympic Games, there has been a 96% increase in affiliated club members from 2010-11 season to 2012-13 season, accompanied by an overall increase in participation at the youth level (~48%; England Handball Association, personal correspondence). However, performance at youth international standard remains poor, with youth female squads yet to qualify for any major international competition. Therefore, to maximise the potential for success, it is important for such nations to develop superior systems to identify and develop talent, which requires comprehensive and up-to-date values on elite players (Carter, Ackland, Kerr, & Stapff, 2005).

Differences in anthropometric and performance characteristics between playing standards are widely available for male team handball players (Matthys et al., 2011; Mohamed et al., 2009; Zapartidis, Vareltzis, Gouvali, & Kororos, 2009a; Gorostiaga, Granados, Ibañez, & Izquierdo, 2005). This research has indicated that elite males encompass anthropometric and performance characteristics deemed more favourable to team handball compared to their lower standard counterparts (Mohamed et al., 2009; Zapartidis et al., 2009a; Gorostiaga et al., 2005). Such data are less prominent in females (Zapartidis et al., 2009a; Granados, Izquierdo, Ibáñez, Ruesta, & Gorostiaga, 2007), making it problematic to understand the most important determinants to compete in elite standard female match-play. In particular, there is a dearth of research assessing both anthropometric and performance characteristics of youth female players of different standards. Zapartidis et al. (2009a) recorded better values for selected female Greek national players in ball velocity and standing long jump, but not in 30 m sprint speed, sit and reach or $\acute{V}O_{2\,max}$. Selected players were also taller, and had greater arm spans than non-selected players, but were similar in body mass, body mass index (BMI), hand length, and hand-spread. However, this study assessed very young players (~13 y) and only provides information from one nation. A deeper understanding of the differences between top-elite, elite and non-elite female team handball players would enable coaches to benchmark players and classify them more precisely in relation to the desired prototype. Such data would help determine those physically capable of achieving success in a particular sport or position within that sport (Vila et al., 2012), and also help in tracking of youth players to adult competition. Accordingly, the present study aimed to examine the differences in anthropometry and performance between non-elite, elite and top-elite youth female team handball players. It was hypothesised that there would be

differences in anthropometry and performance characteristics between all standards, with top-elite fairing most favourably, followed by elite and then non-elite players.

Methods

Participants

In total, 120 female youth team handball players (16.1 ± 1.3 y) were recruited to take part in the investigation, including both outfield players and goalkeepers. This comprised 47 players from Great Britain who were classified as non-elite (15.7 ± 1.3 y, stature: 165.4 ± 5.8 cm, body mass: 61.1 ± 7.8 kg), 44 players from high standard European league club teams who were classified as elite (15.8 ± 1.3 y, stature: 169.3 ± 6.3 cm, body mass: 64.0 ± 9.4 kg), and 29 European international players who were classified as top-elite (17.1 ± 1.1 y, stature: 176.3 ± 6.6 cm, body mass: 71.8 ± 8.6 kg). Players from elite and top-elite groups were from nations that consistently placed within the top five teams at the European Youth Championship and the Youth World Championship, whereas Great Britain or England had never qualified to compete.

Non-elite players all competed for their club (*n*=47), of whom 29 represented Great Britain and/or England (U16 – U19). For the elite players, 27 competed in the highest league for their age category (Denmark: Liga and qualified for the Danish championship; Norway: Bring series), and 17 competed in the second highest league (Spanish Catalan league). All top-elite players competed for their club and performed at international level (U17 – U19). Top-elite U17/ U19 Danish teams were current European Championship and World Championship holders, respectively. All measurements were taken in-season between December 2012 and June 2013. Non-elite and elite players were tested between December and May

during their domestic league competition period, while top-elite players were tested

in June during their international season. After completion of anthropometric

measurements, all performance tests were completed in one day in the same order in

order to minimize disruption to training practices. All players provided written

informed consent and the study was approved by the institute's Research Ethics

Committee and was carried out in accordance with the declaration of Helsinki.

Procedures

Anthropometric characteristics

Standing stature (Seca, Leicester Height Measure, Hamburg, Germany), body mass

(Tanita, BWB-800, Tanita Corporation, Tokyo, Japan), eight skinfolds (Harpenden,

British Indicators, Burgess Hill, UK), five girths (Lufkin Executive Thinline,

W606PM, USA) and two breadths (Roscraft Campbell 10, Canada), were measured

according to the protocols of the International Society for the Advancement of

Kinanthropometry (ISAK; Marfell-Jones, Olds, Stewart, & Carter, 2006). Skinfold

sites were landmarked at: the triceps, subscapular, biceps, iliac crest, supraspinale,

abdominal, front thigh, and medial calf on the right side of the participant's body.

All sites were then measured using callipers with 10 g·mm^{-2} constant pressure. Girths

were measured for the arm (relaxed and flexed/ tensed), waist, hips (gluteal), and

calf, and breadths at the humerus and femur (distance between the medial and lateral

epicondyles). Each measure was taken two or three times, (Stewart, Marfell Jones,

Olds, & Ridder, 2011) by the same Level 1 accredited investigator. Technical error

of measurement was <3% for skinfolds, and <1% for breadths and girths, which

were deemed acceptable by ISAK standards (Carter, 2002). The sum of six and eight

skinfolds was calculated and waist-to-hip ratio was determined by dividing the waist

girth by the gluteal girth. Percentage body fat was derived from skinfolds using the

equation by Durnin and Wormersley (1974), which was then used to calculate fat mass and lean body mass. Somatotypes were determined using methods previously described by Carter and Heath (1990).

Physical performance tests

Prior to test commencement, coaches from each team were provided with testing procedures and were asked to lead a 20 min warm-up including running, sprinting, agility and throwing drills to ensure adequate player preparation. After familiarization to the procedures, all participants completed the same tests in the following order with sufficient recovery between each: maximal counter-movement jump (CMJ), 20 m sprint with 10 m split, throwing velocity, repeated shuttle sprint and jump ability (RSSJA) and the Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1).

Participants began the CMJ (coefficient of variation [CV] = 4.30%) in an upright position, with the hands placed on the hips to minimize any influence from the arms. Participants flexed at the knee to a self-selected depth and then jumped for maximal height. Participants were observed throughout to ensure that landing and take-off position were the same. Jumps that did not meet the stated criteria were not recorded, and in such cases the participant was asked to complete a new jump. Jump height was recorded from flight time using the equation of $9.81 \times \text{flight time}^2 / 8$ (Bosco, Luhtanen, & Komi, 1983) measured using an infrared timing system (Optojump, Microgate S.r.l., Bolzano, Italy) interfaced with a laptop. Peak power was calculated using the formula: CMJ (W) = (60.7 x height [cm]) + (45.3 x body mass [kg]) – 2055. This equation has been used previously (Buchheit, Spencer & Ahmaidi, 2010), and provides an accurate estimation of peak power from jump height (Sayers,

Harackiewicz, Harman, Frykman, & Rosenstein, 1999). Participants performed one practice jump followed by two test jumps with the highest jump height recorded for analysis.

Sprint performance over 20 m (CV = 1.36%) was measured using electronic timing gates (Brower Timing Systems, Microgate, Bolzano, Italy) placed at 0, 10 and 20 m in an indoor sports hall. The use of 10 m split time was based on a similar protocol (Ingesbrigtsen, Jeffreys, & Rodahl, 2013). Players began from a stationary standing start, with their foot behind the 0 m line and began when ready. Participants performed one practice sprint and two test sprints, with ~2 minutes recovery between each sprint. The best 20 m sprint time was recorded for analysis.

Throwing velocity (km·h^{-1}) was assessed using a radar gun (Bushnell Sports Radar Gun, 101911, Kansas City, USA), placed 1 m to the side of the goal post, and perpendicular to the player. Players applied resin as desired to a size 2 handball, and completed maximal effort throws in three conditions without a goalkeeper, based on procedures conducted by Vila and colleagues (2012): (a) standing set throw from 7 m penalty line (i.e. a penalty throw), (b) set throw with 3-step run-up from 9 m, (c) jump throw with 3-step run-up from 9 m. Each participant completed one practice throw and two test throws without a goalkeeper, and the fastest throw was recorded for analysis. Players received ~2 min recovery time between trials with only throws on target selected for analysis (CVs = 3.95%, 3.08% and 4.01% for throw types a, b and c, respectively).

The Repeated Shuttle Sprint and Jump Ability Test (RSSJA; Buchheit et al., 2010) comprised six maximal 2 × 12.5 m out-and-back shuttle sprints (~5 s) starting every

25 s. Participants had ~20 s recovery between sprints, where they were required to decelerate, perform a CMJ, and then an active recovery (covering 36 m ≈ running at 2.1 m·s⁻¹). Averages were calculated for CMJ variables, and times for 10 m, agility (the time between 10 m, and the 2 x 2.5 m turn-around), and total 25 m (CVs = 1.0%, 2.9% and 1.5% for repeated sprints, CMJ height and CMJ power, respectively, Buchheit et al., 2010).

The Yo-Yo IR1-test (Krustrup et al., 2003) required the participant to perform of 2 x 20 m shuttle running bouts, interspersed with 10 seconds recovery at progressive speeds dictated by a pre-recoded audio signal. The final score was recorded as the total distance covered after the second failed attempt to complete the shuttle running bout in the required time. All participants were familiar with this test as part of their normal fitness testing procedures.

Statistical analysis

Data are expressed as mean ± SD. Assumptions of normal distribution and homogeneity were checked using Kolmogrov Smirnoff and Levene tests. A one-way analyses of covariance (ANCOVA) was used to examine for any differences between non-elite, elite and top-elite players in all variables. Age was included as the covariate in order to control for its potential contribution on observed results. All significant effects were followed up with a Bonferroni *post-hoc* tests. Effect sizes and magnitude-based inferences (Batterham & Hopkins, 2006), were also calculated for all variables. Based on the 90% confidence limits, threshold probabilities for a substantial effect were: 0.5% most unlikely, 0.5–5% very unlikely, 5–25% unlikely, 25–75% possibly, 75–95% likely, 95–99.5% very likely, >99.5% most likely. The threshold for the smallest important change was determined as the within-participant

standard deviation (s) x 0.2 (small effect), with 0.3, 0.9 representing, moderate and large effect, respectively. Effects with confidence limits across a likely small positive or negative change were deemed unclear (Hopkins, Marshall, Batterham & Hannin, 2006). A predesigned spreadsheet (Hopkins, 2006) was used for all calculations. Relationships between anthropometric characteristics and markers of performance were conducted using the Pearson-moment correlation (*r*). Analyses were performed using Predictive Analytics Software (PASW) Statistics v.18 (SPSS Inc., Chicago, IL), with the alpha level set at $P < 0.05$.

Results

Analysis revealed differences between standard in a variety of anthropometric (Table 1) and performance (Table 2) characteristics. Top-elite players were taller and had higher body mass than both elite and non-elite counterparts (both $P < 0.001$), and elite were taller than non-elite players ($P = 0.01$). This was accompanied by greater lean body mass in top-elite compared to elite ($P = 0.01$) and non-elite players ($P < 0.001$). Top-elite players also had greater girth measurements for relaxed arm, calf girth, and humerus breadth than both elite and non-elite players (all $P < 0.05$), and greater flexed arm ($P < 0.001$) and gluteal girths ($P = 0.02$) than non-elite players.

There were no differences between standard in individual skinfolds, sum of six or eight skinfolds, fat mass, or waist-to-hip ratio between standard (all $P > 0.05$). Somatotype profile rating (endomorphy-mesomorphy-ectomorphy) for non-elite (4.0 – 3.4 – 2.3) and elite (3.8 – 3.3 – 2.6) players was mesomorphic endomorph, whereas top-elite players were classified as central (3.3 – 3.2 – 2.6). In all cases, endomorphy was the most dominant component, with ectomorphy being the least dominant. There was a significant age effect for relaxed arm girth ($P = 0.04$) and flexed arm girth (P

= 0.01) although differences between standard were apparent independent of this covariate (P = 0.01, P = 0.003, respectively).

Top-elite players out-performed both elite and non-elite players in 20 m sprint, CMJ, all throwing velocity tests, the Yo-Yo IR1 and all variables on the RSSJA test (all P < 0.05), excluding average time to complete 10 m during the RSSJA (P = 0.14). Elite players were only better than non-elite players in throwing velocity (P < 0.001). There was a significant age effect for all performance variables (P < 0.05) with the exception of agility (P = 0.06). However, differences between standard were independent of this covariate in all performance tests (P < 0.05), excluding 10 m maximal sprint (P = 0.20) and 10 m average sprint during the RSSJA (P = 0.14).

*******Table 1 about here*******

*******Table 2 about here*******

Correlational analysis revealed that stature was related to a large number of performance variables, including 20 m sprint (r = -0.264, P = 0.007), average 25 m repeated sprint (r = -0.30, P = 0.002) Yo-Yo IR1 (r = 0.365, P < 0.001), as well as for all associated CMJ variables (r = 0.33 - 0.69, all P < 0.001), and velocity for all types of throw (r = 0.56 - 0.65, all P < 0.001). Body mass was positively correlated to maximal and average power for CMJ (r = 0.77, r = 0.69, both P < 0.001), and was related to velocity for all types of throw (r = 0.39 - 0.49, all P < 0.001).

The sum of skinfolds showed relationships with sprint performance at both 10 m and 20 m (r = 0.42 – 0.50, both P <0.001), and for average 25 m repeated efforts (r = 0.54, P < 0.001), indicating that higher skinfold values were associated with slower times. A similar pattern was also apparent for the Yo-Yo IR1 test (r = 0.49, P <

0.001). Higher skinfold values were found to negatively affect both maximal and average CMJ height ($r = -0.559$, $r = -0.57$) as well as throwing velocity for standing set throw ($r = -0.29$, $P = 0.002$), set throw with 3-step run-up ($r = -0.29$, $P = 0.003$) and jump throw with 3-step run-up ($r = -0.34$, $P < 0.001$).

Gluteal girths had an overall moderate effect on power parameters for CMJ ($r = 0.55 – 0.60$, $P < 0.001$), and throwing velocity (penalty: $r = 0.33$, $P = 0.001$; running: $r = 0.33$, $P = 0.001$, jumping: $r = 0.23$, $P = 0.02$). Similar results were also found for calf girth and CMJ power parameters ($r = 0.60 – 0.65$, both $P < 0.001$), and throwing velocity ($r = 0.35 - 0.41$, all $P < 0.001$), indicating the positive contribution of these characteristics to performance.

Discussion

This is the first study to include detailed analysis on both anthropometric and performance characteristics on a large sample of female players representing three standards of team handball performance. These findings reveal different anthropometric and performance profiles between youth top-elite international compared to both youth elite and non-elite female team handball players, and highlight that youth elite and non-elite players differ only in few characteristics. This study improves understanding of the quintessential characteristics needed to achieve excellence so that selection processes can be modelled accordingly.

Anthropometric data revealed that youth top-elite players were on average 11 cm taller and 11 kg heavier than non-elite players, and 7 cm taller and 8 kg heavier than elite players. These findings are similar to differences reported between standard in

youth (Zapartidis et al., 2009a) and female adults (Granados et al., 2007). Youth top-elite players also had greater girth and breadth measurements and higher overall lean mass than their elite and non-elite counterparts, which may indicate more developed musculature and skeletal robustness (Bourgois et al., 2001). Although youth top-elite players were heavier with similar body fat compared to non-elite and elite players, they possessed more lean muscle mass. Such findings re-affirm those of other studies assessing elite and non-elite adult female (Granados et al., 2007) and male players (Gorostiaga et al., 2005). Collectively, the anthropometric data reveal that above average stature and higher body mass are key physical requisites for elite female handball players. This is confirmed by the correlations observed between anthropometric and performance characteristics, which reinforces the influence of these physical attributes on a handball player's ability to perform game-specific actions. Interestingly, British non-elite players from this study had similar statures to the English average for 16 - 24 years (1.64 m, Health Survey for England, 2010), which is in contrast to elite youth female team handball players who tended to be taller than their national average (Ingebrigtsen et al., 2013; Zapartidis et al., 2009b). This highlights issues surrounding selection of tall players in Great Britain, which needs to be addressed for future talent identification programmes. Body mass for top-elite players in this study were also similar to elite adult females (67 – 70 kg, Michalsik, 2013b; Vila et al., 2012; Milanese et al., 2011; Granados et al., 2007), suggesting selection of youth players with a higher body mass is preferable. Somatotypes did not differ between groups, suggesting that appropriate physiques were found in all standards.

Performance characteristics

Large differences in throwing velocity between all playing standards reaffirms that improved throwing velocity is a requirement of higher standard players (Wagner et al., 2012; Wagner et al., 2010; Granados et al., 2007; Gorostiaga et al., 2005**)**. Indeed, the final outcome of the match is dependent on the team scoring the most goals, requiring players to execute throws that often require high velocity to beat the goalkeeper (Zapartidis et al., 2009c; Gorostiaga et al., 2005). Overall throwing velocity was ~16 – 27% higher in youth female top-elite compared to non-elite players when taking into account all three throw types, which was substantially greater than differences reported between elite and amateur adult females (11%; Granados et al., 2007). Slower throwing velocities in our youth non-elite players might be explained by poorer technique and lower strength and/ or power of the upper and lower body limbs, subsequently resulting in reduced efficiency during the transfer of momentum through the pelvis and trunk to the throwing arm (Wagner et al., 2010). Indeed, both strength and power (Chelly et al., 2010; Marques et al., 2007; Granados et al., 2007) and technique (Wagner et al., 2012; Wagner et al., 2010; van den Tillaar & Ettema, 2007), are positively related to throwing velocity. The lower overall lean musculature and lower CMJ power observed in the non-elite and elite players support this, suggesting that players should be coached to improve muscular and technical characteristics to ensure development of this essential skill.

CMJ performance for top-elite players was ~4-5 cm higher than elite and non-elite players, respectively. Reasons for this might include a number of integrating factors comprising greater training focus on improving jumping performance and well-developed selection processes for top-elite players. Better performance in top-elite players is unsurprising given the important role of jumping in various aspects of the

game, such as throwing and blocking (Michalsik et al., 2014a; Buchheit et al., 2010). Despite this, other research has failed to find differences in vertical jump performance between elite and amateur females (Granados et al., 2007). It is notable that CMJ height in our youth non-elite (~28 cm) and elite (~26 cm) players was comparable to elite age-matched Norwegian players (~25 – 27 cm, Ingebrigtsen et al., 2013), whereas our youth top-elite players outperformed some (~28 – 31 cm, Ronglan et al., 2006), but not all (~43 cm, Vila et al., 2012) elite adult players. When muscle power was estimated from jump performance, there were large differences observed when top-elite players were compared to elite and non-elite players. These findings are likely a result of overall greater body mass of elite players, alongside higher musculature, thus suggesting that measures of lower limb power are useful discriminators of performance in female youth players.

The ability to sprint and change direction at high velocities is an important determinant of team handball performance in order to reposition oneself during transition between phases of attack and defence, as well as during fast breaks and offensive breakthroughs (Michalsik et al., 2013a; Michalsik et al., 2014a). This study observed that 20 m maximal sprinting performance was superior in top-elite players compared to lower standard players, while no differences were observed between elite and non-elite players. Previous studies have observed differences between standard in youth males (Zapartidis et al., 2009a), and adult females (Granados et al., 2007). Notably, all players in our study were substantially slower (~3.65 s and ~ 3.50 s) than adult national Norwegian players over 20 m (~3.10 s), although authors do not state whether players began from a standing start or performed a prior run-up.

Top-elite players also performed better than non-elite and elite players on all variables of the RSSJA, excluding average 10 m sprint, supporting the utility of this

multi-component test when assessing large numbers of players for a range of physical skills. Performance of repetitive short explosive efforts with frequent changes in direction could be crucial for match outcomes (Michalsik et al., 2013a), with jumps occurring predominately after high intensity runs (Buchheit et al., 2010). This study confirms the findings of Buchheit and colleagues (2010), highlighting its applicability to distinguish between playing standards for physical characteristics.

Results for the Yo-Yo IR1 demonstrated youth top-elite national players ran further distances (~1660 m) than reported for adult players from the upper half of the Danish Premier League (~1440 m, Michalsik et al., 2014a). This is most likely explained by individual differences as training practices were similar between Danish adults and youth players (personal correspondence). Superior performance of top-elite players compared to non-elite and elite groups reaffirms findings from male youth team handball (Matthys et al., 2011) and indicates the distance covered during the Yo-Yo IR1 distinguishes between top-elite and lower standard youth. Thus, the ability to perform repeated intense running exercise and to be able to recover quickly between work bouts is important during elite team handball match-play (Michalsik, Madsen & Aagaard, 2014b). These data provide the first normative values for practitioners to inform selection and highlight physical training requirements for youth females regarding the ability to perform repeated intense running exercise during team handball match-play.

Most research to assess the association between anthropometric and performance characteristics in team handball has focussed on throwing velocity (Wagner et al., 2010; Gorostiaga et al., 2005; van den Tillaar & Ettema, 2004), with little information available on other key determinants of success. Using correlational analysis, this study showed that both stature and body mass were positively related to

throwing velocity, and CMJ variables, with benefits of greater stature extending to better maximal and repeated sprinting performance, and better aerobic intermittent performance on the Yo-Yo IR1. Greater gluteal and calf girths were also beneficial for throwing velocity and CMJ power, suggesting that increased muscle mass in these areas contribute to actions involving a strength and power component.

Despite there being no difference between playing standard for body fat, this variable was related to a plethora of performance variables, indicating slower maximal and repeated sprinting times, and reduced Yo-Yo IR1 distance as body fat increased. Throwing velocity and CMJ height were also negatively affected by higher body fat values, indicating the importance of this characteristic to key performance determinants of team handball. The potential for certain anthropometric characteristics to have a positive impact on physical performance promotes the use of normative values from this study when selecting players.

A limitation to this study is that players in the top-elite group were 17.1 years old, compared to 15.7 – 15.8 years old for non-elite and elite players. However, when included as a covariate, differences found in anthropometric characteristics between standard were independent of age. For performance characteristics, differences between standard were apparent despite age being a significant contributor. The outcome of this is ~1 year longer training experience in top-elite players in comparison to elite and non-elite players, which potentially allows greater physical development from training practices.

Conclusions

In conclusion, this study indicates a large disparity in anthropometric and physical performance characteristics when top-elite players are compared to both elite and

non-elite youth female team handball players. As British non-elite players were found to differ from elite players only in stature, arm girth and throwing velocity, coaches might aid talent identification and development by focussing on these aspects. The present data provide normative values to be used by coaches and re-affirm the importance of a multitude of characteristics for successful youth female competition.

References

Bayios, I. A., Bergeles, K., Apostolidis, N. G., Noutsos, K. S., Koskolou, M. D. (2006). Anthropometric, body composition and somatotype differences of Greek elite female basketball, volleyball and handball players. *Journal of Sports Medicine and Physical Fitness, 46,* 271–280.

Batterham, A.M., & Hopkins, W.G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance, 1,* 50–57.

Bloomfield, J., Ackland, T. R., & Elliott, B. C. (1994). *Applied anatomy and biomechanics in sport*. Melbourne, VIC: Blackwell Scientific.

Bosco, C. Luhtanen, P., & Komi, P.V. (1983). A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology and Occupational Physiology, 50*, 273-282.

Bourgois, J., Claessens, A. L., Janssens, M., van Renterghem, B., Loos, R., Thomis, M., Phillippaerts, R., Lefevre, J., & Vrijens, J. (2001). Anthropometric characteristics of elite female junior rowers. *Journal of Sports Sciences, 19*, 195-202.

Buchheit, M., Spencer, M., & Ahmaidi, S. (2010). Reliability, usefulness, and validity of a repeated sprint and jump ability test. *International Journal of Sports Physiology and Performance, 5,* 3–17.

Carter, J. E. L., Ackland, T. R., Kerr, D. A, & Stapff, A. B. (2005). Somatotype and size of elite female basketball players. *Journal of Sports Sciences, 23*, 1057–63.

Carter, J. E. L. (2002). The Heath-Carter anthropometric somatotype: Instruction manual. Retrieved from http://www.somatotype.org/Heath-CarterManual.pdf

Carter, J.E.L., & Heath, B.H. (1990). *Somatotyping: Development and applications*. New York: Cambridge University Press.

Chaouachi, A., Brughelli, M., Levin, G., Boudhina, N. B. B., Cronin, J., & Chamari, K. (2009). Anthropometric, physiological and performance characteristics of elite team-handball players. *Journal of Sports Sciences, 27*, 151–7.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Durnin, J. V., & Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged from 16 to 72 years. *British Journal of Nutrition, 32,* 77-97.

Granados, C., Izquierdo, M., Ibañez, J., Bonnabau, H., & Gorostiaga, E. M. (2007). Differences in physical fitness and throwing velocity among elite and amateur female handball players. *International Journal of Sports Medicine, 28*, 860–7.

Gorostiaga, E., Granados, M. C., Ibañez, J., & Izquierdo, M. (2005). Differences in physical fitness and throwing velocity among elite and amateur male handball players. *International Journal of Sports Medicine, 25*, 1-8.

Hasan, A. A., Reilly, T., Cable, N. T., & Ramadan, J. (2007). Anthropometric profiles of elite Asian female handball players. *The Journal of Sports Medicine and Physical Fitness, 47*, 197–202.

Health Survey for England (2010). Retrieved from
http://www.hscic.gov.uk/pubs/hse09report

Hopkins, W.G. (2006). Spreadsheets for analysis of comparing group means.
Sportscience,10, 46–50.

Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J.(2009). Progressive
statistics for studies in sports medicine and exercise science. *Medicine and
Science in Sports and Exercise, 41*, 3–12.

Ingebrigtsen, J., Jeffreys, I., Rodahl, S. (2013). Physical characteristics and abilities
of junior elite male and female handball players. *Journal of Strength and
Conditioning Research, 27,* 302-309.

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A.,
Pedersen, P. K., et al. (2003). The yo-yo intermittent recovery test:
physiological response, reliability, and validity. *Medicine and Science in
Sports and Exercise, 35*, 697–705.

Malina, R., M., Bouchard, C., Bar-Or, O. (2004). *Growth, maturation, and physical
activity* (2nd ed.). Human Kinetics: Leeds.

Marfell-Jones, M., Olds, T., Stewart, A., & Carter, L. (2006). *International
standards for anthropometric assessment.* Potchefstroom, South Africa:
International Society for the Advancement of Kinanthropometry.

Matthys, S. P. J., Vaeyens, R., Vandendriessche, J., Vandorpe, B., Pion, J., Coutts,
A. J., Lenoir, M., et al. (2011). A multidisciplinary identification model for
youth handball. *European Journal of Sport Science, 11,* 355–363.

Michalsik, L. B., Aagaard, P., & Madsen, K. (2013a). Locomotion characteristics
and match-induced impairments in physical performance in male elite team
handball players. *International Journal of Sports Medicine*, 34, 590-599.

Michalsik, L.B. (2013b). Physical Demands of Training and Match-Play in the
Female Elite Team Handball Player. In: European Handball Federation
Scientific Conference 2013 - Women and Handball: Scientific and Practical
Approaches. Proceedings of the second International Conference on Science in
Handball, Vienna, Austria, 22-23 Nov; 77-83.

Michalsik, L. B., Madsen, K., & Aagaard, P. (2014a). Match performance and
physiological capacity of female elite team handball players. *International
Journal of Sport Medicine*, 35, 595-607.

Michalsik, L. B., Madsen, K., & Aagaard, P. (2014b) Physiological capacity and
physical testing in male elite team handball. *Journal of Sports Medicine and
Physical Fitness*, Epub ahead of print

Milanese, C., Piscitelli, F., Lampis, C., & Zancanaro, C. (2011). Anthropometry and body composition of female handball players according to competitive level or the playing position. *Journal of Sports Sciences, 29*, 1301–9.

Mohamed, H., Vaeyens, R., Matthys, S., Multael, M., Lefevre, J., Lenoir, M., & Philppaerts, R. (2009). Anthropometric and performance measures for the development of a talent detection and identification model in youth handball. *Journal of Sports Sciences, 27*, 257–66.

Rogulj, N., Srhoj, V., Nazor, M., Srhoj, L., & Cavala, M. (2005). Some anthropologic characteristics of elite female handball players at different playing positions. *Collegium Antopologicum, 29,* 705-709.

Ronglan, L. T., Raastad, T., & Børgesen, A. (2006). Neuromuscular fatigue and recovery in elite female handball players. *Scandinavian Journal of Medicine and Science in Sports, 16*, 267–73.

Sayers, S. P., Harackiewicz D. V., Harman, E. A, Frykman, P. N., Rosenstein M. T. (1999). Cross- validation of three jump power equations. *Medicine and Science in Sports and Exercise, 31,* 572–577.

Stewart, A., Marfell-Jones, M., Olds, T., & de Ridder, H. (2011).International standards for anthropometric assessment (p. 125). Lower Hutt, New Zealand: International Society for the Advancement of Kinanthropometry.

Tanner, J. M., Hughes, P. C. R., Whitehouse, R. H. (1981). Radiographically determined widths of bone, muscle and fat in the upper arm and calf from 3-18 years. *Annals of Human Biology, 8*, 495-517.

van den Tillaar, R., & Ettema, G. (2007). A three-dimensional analysis of overarm throwing in experienced handball players. *Journal of Applied Biomechanics, 23,* 12–19.

Vila, H., Manchado, C., Rodriguez, N., Abraldes, J. A., Alcaraz, P. E., & Ferragut, C. (2012). Anthropometric profile, vertical jump, and throwing velocity in elite female handball players by playing positions. *Journal of Strength and Conditioning Research*, 31, 2146–2155.

Wagner, H., Pfusterschmied, J., Von Duvillard, S. P. & Müller, E. (2012). Skill-dependent proximal-to-distal sequence in team-handball throwing, *Journal of Sports Sciences, 30*, 21-29.

Wagner, H., Buchecker, M., Von Duvillard, S. P., Müller, E. (2010). Kinematic description of elite vs . low level players in team-handball jump throw. *Journal of Sports Science and Medicine, 9*, 15–23.

Zapartidis, I., Vareltzis, I., Gouvali, M., & Kororos, P. (2009a). Physical Fitness and Anthropometric Characteristics in Different Levels of Young Team Handball Players. *The Open Sports Sciences Journal*, *2*, 22–28.

Zapartidis, I., Toganidis, T., Vareltzis, I., Christodoulidis, T., Kororos, P., & Skoufas, D. (2009b). Profile of young female handball players by playing position. *Serbian Journal of Sports Sciences*, *3*, 53–60.

Zapartidis, I., Skoufas, D., Vareltzis, I., Christodoulidis, T., Toganidis, T., & Kororos, P. (2009c). Factors Influencing Ball Throwing Velocity in Young Female Handball Players. *The Open Sports Medicine Journal*, *3*, 39–43.

Appendices

Table captions

Table 1. Anthropometric characteristics and comparison of non-elite, elite and top-elite female youth team handball players.

Table 2. Performance characteristics and comparison of non-elite, elite and top-elite female youth team handball players.