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Mind, body, and shuttle: multidimensional benchmarks for talent identification in male youth badminton

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ABSTRACT: The aim of the study was to identify benchmarks for anthropometric, physical performance, motor coordination, and psychological characteristics by comparing youth badminton players of different levels through the use of a multifactorial test battery. Sixty-one male participants aged 12–18 years were divided into three groups: elite (N = 10), sub-elite (N = 24), and novice (N = 27). Standard test batteries for anthropometry (including measures to estimate biological maturity), physical performance, and motor coordination were applied, as well as the modified PCDEQ2 questionnaire for psychological characteristics of youth athletes (Hill, 2016). Multivariate analyses of covariance (MANCOVAs) with age and biological maturity as covariates were used to investigate differences between skill levels. A discriminant analysis was used to reveal to what extent participants could be correctly assigned to their skill group. Significant differences were found in physical performance (explosive power, flexibility, speed, and endurance), BMI and motor coordination. In the psychological domain, perfectionism was found to be significantly different and elites scored highest. The discriminant analysis showed that 100% of the participants were correctly classified and 80.0% were correctly cross validated. These results significantly add to the previously limited youth players' reference values, and confirm the value of a generic, i.e. without sport-specific testing, multifactorial approach to talent identification in youth badminton.

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INTRODUCTION

Many racquet sport associations use talent identification and development programmes to help young, sub-elite players to develop into elite players [1]. Hence, the importance of acquiring knowledge on youth badminton players' profiles becomes more important as a cornerstone of identification and development processes throughout young players' careers.

Physical characteristics such as anthropometry and physical performance have been identified as critical and contributing factors for (adult) athletic performance in various sports [2]. In elite badminton, mixed somatotypes with a combination of endomorphic, mesomorphic, and ectomorphic characteristics have been reported [3, 4]. It is clear that there is no such thing as one unique anthropometric profile that is a prerequisite for participating in the highest level of play.

Since racquet sports have developed into fast-paced, explosive sports in the past decades, the attention placed on the physical abilities has increased as well [5], a tendency that requires valid benchmarks for different age categories to assist both coaches and scientists in their work [6]. The physical demands are continually changing, with players in action demonstrating intense rhythmic movement involving shuffling, jumping, twisting, stretching, striking, etc., all in a context of severe temporal pressure [7]. Arm strength, leg strength, agility, spine flexibility, wrist flexibility, counter movement jumps for power and height, reactive speed times, squat jumps, maximal heart rate, aerobic and anaerobic ability are just some of the physical characteristics that scientists have taken into consideration when testing badminton elites [7–9]. The aspect of motor coordination in badminton players is largely unexplored. However, there is – at least indirect – evidence from other sports that this characteristic is an important prerequisite to acquire technical skills in an effective way. Vandorpe et al. [10] demonstrated a significant association between general motor coordination and competitive performance in a young elite gymnast training in the same programme for two years. Similar findings were reported in female volleyball [11]. A study by di Cagno et al.[12] also supported the assumption that general motor coordination should be considered as an estimate of future development, rather than the athlete's current performance, and should be included in identification, selection and development programmes.

Apart from the physical characteristics, racquet sport players need highly developed tactical skills, concentration and mental toughness throughout a match and also volition, self-regulation and social skills to persevere during extensive development programmes [5, 13–16]. Psychological skills have often been a key indicator in determining the stronger athletes from weaker ones. Very early studies showed that champions and less successful athletes across several sports can be differentiated by the type of cognitive strategies they employ [17]. Within the various types of coping strategies, the trait and process perspectives allow individuals to be classified according to their stable coping styles [18]. Psychological and mental skills hold key value in racquet sports, and therefore in this study a psychological questionnaire was used as a tool to discriminate the manner in which different levels of athletes employ mental strategies as part of their routine. As psychological skills are not static but rather changeable over time, it would be a valuable asset for coaches to have a baseline idea of their athlete's psychological behaviour and individual characteristics to assist with the planning of their training programme.

A factor that is known to affect anthropometric and physical performance measures is the athlete's biological age. Biological age can vary as much as three years in individuals of the same chronological age [19]. As children mature, increased height and weight have an impact on aerobic and anaerobic capacities, muscular strength, power and running speed, leading to a distinct advantage in sporting performance for individuals who are more biologically mature within an age group [19–21]. From this point of view, biological age should be taking into account when using reference values for test batteries in talent identification and development programmes.

The implementation and execution of an evidence-based talent identification (TID) and development programme can be instrumental in formulating a pathway for young athletes; however, this is no easy undertaking. Adopting less-than-perfect early identification practices increases the risk of missing talented players and can have profound consequences for the overall quality of the talent pool going forward [22]. A talent and identification development system (TIDS) [23, 24] is an approach to using limited resources in the most efficient way possible [25]. As it refers to assessing talent within young athletes, most studies compare a range of characteristics between playing levels with the assumption that differences in characteristics between playing standards equate to talent [25]. These studies and methodologies only measure performance at a specific time point with little regard for how such characteristics relate to future performance outcomes or potential [26]. Such an approach assumes that talent is a fixed capacity, which is reflected in performance at that specific time point [27, 28]. As a result, evaluating athlete potential and predicting future adult performance within young athletes remains a central problem for all talent identification researchers and practitioners [29].

It is important to remember that the ability to effectively measure and understand the demands of sport can often be difficult due to the complexity of sports performance [25]. The evolvement and advancement of sport over time makes predicting the future of sport and whether athletes will be successful a difficult challenge [25]. For example, in the sport of soccer there have been increases in the volume of high-intensity running distance alongside the frequency and successfulness of technical characteristics [30, 31]. In spite of the amount of information on profiles of elite badminton players, these profiles are seldom those of youth players. Apart from two studies containing information on anthropometric characteristics of youth badminton players [32] no study has approached the topic from a more diverse (comparison of skill levels) and multifactorial (multiple scientific domains) perspective. Multifactorial approaches to talent identification contain dimensions such as anthropometry, maturity, motor competence, fitness and coach skill, and have been applied in other sports, including Australian football [33] and soccer [34]. Therefore, the aim of the current study was to identify benchmarks and key differences between youth badminton players of different levels from a multifactorial perspective with a set of non-sport specific tests that encompass the domains of anthropometry, physical performance, general motor coordination, and psychological skill. It is expected that elite players will outperform their lower-ranked peers and non-players in each of these domains, and that the combination of test scores will allow a correct classification of each player in his/her skill level.

MATERIALS AND METHODS

Participants

A total of 61 male youth badminton players (12–18) volunteered to participate. The elite group (N = 10, 15.79 ± 1.89 years) competed at the highest level of Belgian competition (A, B1 & B2), international junior or senior tournaments. They were selected from the Badminton Top Sport School, a special programme for young elite players. The sub-elite group (N = 24, 15.41 ± 1.56 years), participated in the fourth, fifth and sixth levels of competition in Belgium (C2, C1 & D), and were recruited from different badminton clubs in Belgium. The novice group consisted of non-players (N = 27, 15.22 ± 1.33 years), although most of them were recreationally active in other sports.

Procedure and measurements

Anthropometry

Body height and sitting height were measured with a calibrated stadiometer (to the nearest 0.1 cm; Seca and Harpenden, Holtain Ltd., UK). A digital balance scale with a foot-to-foot bioelectrical impedance system (Tanita, BC420SMA, Weda B.V., Holland) was used for the measurement of body weight (an accuracy of 0.1 kg), estimation of fat percentage (to the nearest 0.1%), and body mass index (BMI) calculation [35]. Age of peak height velocity (APHV), determined by Mirwald's gender-specific formula, was used to estimate maturity offset [36]. It should be noted that when using this formula one should leave room for estimation error. The Mirwald APHV formula has been used successfully to predict the timing of the growth spurt in youth soccer players [37].

TABLE 1.

Psychological Factors	Items
1: Adverse Response to Failure	Focus, distraction control, goal setting and resilience
2: Imagery and Active Preparation	Planning and organization
3: Self-Directed Control and Management	Self-regulation, self-control, quality practice, planning and organization, goal setting and performance evaluation
4: Perfectionistic Tendencies	Passion, anxiety and performance
5: Seeking and Using Social Support	Role clarity and commitment.
6: Active Coping	Resilience, commitment, goal setting and focus and role clarity
7: Clinical Indicators	Depression, eating disorders, and behavioural change

Physical performance tests

Participants completed 12 physical tests without shoes, except for tests where running and jumping were required. Procedures for the following tests were conducted according to the EUROFIT guidelines [38, 39]. The highest score on the sit and reach test (2 attempts to the nearest 0.5 cm) was used to evaluate trunk flexibility. The knee push-ups and sit-ups were done with the maximum number counted in 30 seconds. The standing broad jump (to the nearest 1 cm) was used to evaluate lower limb explosive power (best score from two trials). A 10 × 5 m shuttle run (accuracy of 0.001 seconds) was conducted for measuring speed and change of direction ability and Microgate timing gates were used for this assessment. The test was performed twice and times were split at 5 m, 10 m, 20 m, and 30 m, with the best times being used for data. A 30 m sprint test was performed (accuracy of 0.001 s, MicroGate Racetime 2 chronometry and Polifemo Light Photocells; MicroGate, Italy). Endurance was measured by a 20 m endurance shuttle run (ESHR). The maximum counter movement jump (CMJ) height was measured using OptoJump technology (accuracy: 0.1 cm; Microgate, Italy). The CMJ was executed without arm swing and with arm swing, three jumps for each form of the exercise were counted, and the best attempt out of three jump was used. Reliability of the tests above is reported elsewhere [38, 39].

Motor coordination tests

Motor coordination was evaluated by the short version of the *Körperkoordinations Test für Kinder*, with good established reliability and validity [40, 41]. The moving sideways test used a wooden (20 × 20 cm) platform for the participant to move sideways along a straight line in a 20 seconds. The sum of the number of moves over two trials was scored. In the jumping sideways test participants jumped with both legs over a thin wooden slat for 15 seconds. The number of jumps over two trials was the total score. Walking backwards on a balance beam was done with three beams with widths of 6 cm, 4.5 cm, and 3 cm; participants must complete 3 trials for each beam, and the total number of steps was counted with a maximum of 72 steps.

Psychology questionnaire

The questionnaire used was the Psychological Characteristics of Developing Excellence Questionnaire version 2 (PCDEQ2) (see Appendix). The Psychological Characteristics Of Developing Excellence Questionnaire (PCDEQ) [42] was originally designed to assess the range of psychological characteristics of developing excellence (PCDE) [43] and also the wider range of psychological characteristics that influence the talent development process both positively and negatively [44]. PCDE underpin effective development of potential and the attainment of elite performance [42]. The questionnaire has a good test-retest reliability [44].

Discriminant analysis

The utility of coefficients was tested on a new sample or cross validated. The leave-one-out classification (jackknifed classification) means that the data from the case were left out when the coefficients used to assign a group were computed. Each case had a set of coefficients that were developed from all other cases. Jackknifed classification gave a more realistic estimate of the ability of predictors to separate groups.

Statistical analysis

Statistical analysis was performed using SPSS version 24. Descriptive statistics are expressed as means and standard deviations. An analysis of homogeneity of variance was performed. Separate multivariate analyses of variance (MANOVAs) for each of the clusters of dependent variables (anthropometrics, physical performance, motor coordination, and psychological characteristics) were applied followed by multivariate analyses of covariance (MANCOVAs) with age and biological maturity as covariates (separately and then together). Partial eta squared was reported to evaluate effect size. Discriminant analyses were done to assign each participant to one of the skill levels. The significance level was $p < 0.05$.

Discriminant analysis

Discriminant analysis is a linear classification model assigning cases to groups. The goal of the discriminant analysis (DA) is to predict group membership from a set of predictors. In DA the independent variables are the predictors and the dependent variables (grouping variables) are the groups. The DA interprets the pattern of differences among the grouping variables as a whole in an attempt to understand the dimensions along which groups differ [45].

Ethics

This project was conducted according to the Declaration of Helsinki and approved by the local Ethics Committee (EC/2017/1548; Ghent Belgium). All data were analysed confidentially.

RESULTS

The multivariate and univariate results from the MANCOVAs are discussed below. The results of the MANOVAs can be consulted in Table 2.

Anthropometry

There was a multivariate effect of group ($F = 23.207$; $df = 2$; $p < 0.001$). Univariate group BMI was significant ($F = 15.867$; $df = 2$; $p < 0.001$), revealing that BMI increased with increasing skill level, with all groups significantly differing from each other. No other differences were observed, in spite of a tendency towards higher values for height dimensions in players competing at a higher level.

Physical performance

There was a multivariate effect of group for the physical performance tests ($F = 4.412$; $df = 2$; $p < 0.001$). Significant univariate differences were found for standing broad jump ($F = 7.049$; $df = 2$; $p = 0.002$), shuttle run ($F = 19.050$; $df = 2$; $p < 0.000$), endurance shuttle run ($F = 14.620$; $df = 2$; $p < 0.000$), CMJ (w/o arm swing) ($F = 10.076$; $df = 2$; $p < 0.000$) and CMJ (w/arm swing) ($F = 7.301$; $df = 2$; $p = 0.002$). Scores on these tests were always higher in players of higher skill level (Table 2).

Motor coordination

There was a multivariate effect for motor coordination ($F = 3.697$; $df = 2$; $p = 0.002$). At univariate level, jumping sideways ($F = 11.323$; $df = p < 0.000$) and moving sideways ($F = 4.131$; $df = 2$; $p = 0.021$) increased with increasing skill level (Table 2) and were found to be significant. Post hoc tests for jumping sideways showed that the elites differed from sub-elites and novices and the scores increased with skill levels. In moving sideways there were differences between the elites and novices, with elites having the highest scores.

Psychological questionnaire

There was no multivariate effect for the psychological questionnaire as a whole ($F = 1.416$; $df = 2$;$p = 0.162$). Out of the seven factors for this condition, only perfectionism was scored differently between groups ($F = 4.800$; $df = 2$; $p = 0.012$). Post hoc tests also showed that in perfectionism the elites differed from both the sub-elites and novice groups, with the elites having much higher scores than their lower ranked counterparts. No other univariate differences between levels of skill were found.

Discriminant analysis

Discriminant analysis (DA) on all tests was applied to predict group membership from these predictor variables [45]. All characteristics contributed to the discrimination of groups. The analysis reported 55 valid cases (90.2%), which was due to missing test scores from six of the participants. Wilk's lambda, representing the proportion of total variance in the discriminant scores not explained by differences among groups, was > 0.001. The DA resulted in a 100% correct classification of players, and 80.0% of cross-validated grouped cases were correctly classified (see Figure 1). In the cross validated run, eleven of the participants were incorrectly grouped: 3 elites, 7 sub-elite athletes and 1 novice. One elite was classified as a novice (see Table 3).

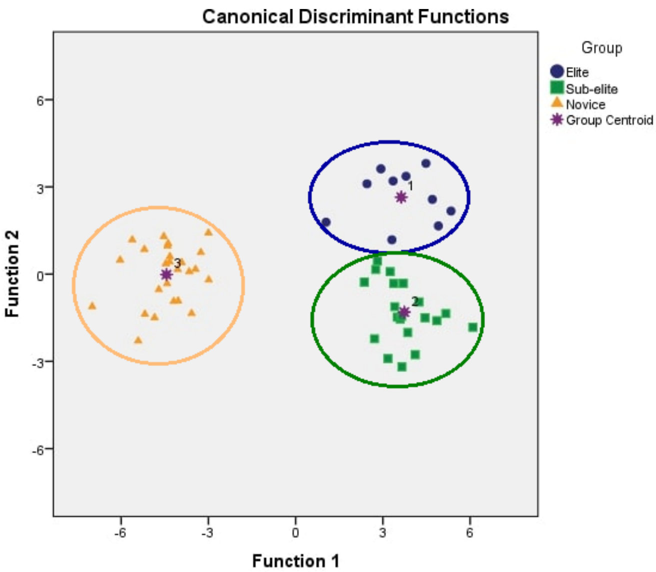

FIG. 1. The scatter plot has the canonical discriminant function coefficients as its axes, with Function 1 on the x-axis and Function 2 on the y-axis. The three-group cluster with two-dimensional space indicates that the functions are clearly discriminated among the three skill groups.

TABLE 2. MANOVA/MANCOVA with mean and standard deviations from the descriptive analysis; F and p values for comparison of participant's skill level.

	Elite Mean (SD) (N = 10)	Sub-elite Mean (SD) (N = 24)	Novice Mean (SD) (N = 27)	MANOVA [F(p)]	Effect Size Partial Eta Squared	Covariate Maturity Offset [F(p)]	Covariate Age [F(p)]	MANCOVA [F(p)]	Effect Size Partial Eta Squared
Anthropometric Characteristics				**23.604 (< 0.001)**	**0.68**	**90.417 (< 0.001)**	**20.251 (< 0.001)**	**23.207 (< 0.001)**	**0.69**
Body Height (cm)	175.8 (8.1)	168.7 (10.8)	167.8 (11.8)	2.028 (0.141)	0.06	240.809 (< 0.001)	15.245 (< 0.001)	0.681 (0.510)	0.02
Body Weight (kg)	65.7 (10.6)	56.4 (13.5)	56.4 (14.6)	1.933 (0.154)	0.00	107.374 (< 0.001)	29.058 (< 0.001)	0.389 (0.680)	0.01
Sitting Height (cm)	90.9 (4.0)	85.7 (6.3)	86.7 (6.6)	2.495 (0.091)	0.07	235.375 (< 0.001)	556.074 (< 0.001)	0.009 (0.991)	0.00
Body Fat Percentage (%)	11.5 (3.0)	11.0 (5.4)	13.2 (6.9)	0.945 (0.395)	0.03	1.275 (0.264)	16.614 (< 0.001)	0.212 (0.810)	0.00
Body Mass Index (kg/m²)	21.11[cz] (1.9)	19.55[cz] (3.2)	16.66[abxy] (3.5)	9.201 (< 0.001)	0.24	35.865 (< 0.001)	17.927 (< 0.001)	15.867 (< 0.001)	0.36
Physical Performance Characteristics				**4.628 (< 0.001)**	**0.54**	**7.756 (< 0.001)**	**2.661 (< 0.009)**	**4.412 (< 0.001)**	**0.54**
Sit and Reach (cm)	24.8[bc] (6.6)	17.2[a] (8.2)	16.6[a] (8.2)	4.091 (0.022)	0.12	4.309 (0.043)	1.336 (0.253)	2.492 (0.092)	0.08
Knee Push-Ups (n/30s)	35 (8)	31 (5)	29 (7)	2.726 (0.74)	0.08	0.019 (0.890)	1.184 (0.281)	1.769 (0.180)	0.06
Sit-Ups (n/30s)	35 (6)	32 (5)	32 (7)	1.013 (0.370)	0.03	0.006 (0.938)	7.205 (0.010)	0.774 (0.466)	0.02
Standing Broad Jump (cm)	220[bcyz] (19)	190[ax] (28)	182[ax] (24)	8.226 (< 0.001)	0.22	8.166 (0.006)	0.465 (0.498)	7.049 (0.002)	0.20
Shuttle Run (s)	15.798[cz] (1.8)	17.643[cz] (2.3)	20.351[abxy] (2.0)	20.499 (< 0.001)	0.41	0.914 (0.343)	7.240 (0.009)	19.050 (< 0.000)	0.40
Sprint (5m) (s)	1.194 (0.1)	1.258 (0.1)	1.247 (0.1)	1.145 (0.325)	0.39	7.461 (0.008)	0.000 (0.988)	0.174 (0.841)	0.00
Sprint (10m) (s)	1.955 (0.1)	2.095 (0.2)	2.086 (0.2)	2.436 (0.097)	0.07	9.911 (0.003)	0.067 (0.796)	0.721 (0.491)	0.02
Sprint (20m) (s)	3.271[c] (0.2)	3.551 (0.4)	3.597[a] (0.3)	4.060 (0.022)	0.12	7.406 (0.009)	0.466 (0.498)	2.132 (0.128)	0.07
Sprint (30m) (s)	4.560[c] (0.3)	4.962 (0.7)	5.108[a] (0.4)	3.808 (0.028)	0.11	9.911 (0.003)	0.170 (0.681)	2.103 (0.132)	0.07
ESHR (m)	11.7[bcyz] (1.8)	7.6[ax] (2.3)	7.3[ax] (2.1)	15.536 (< 0.001)	0.35	0.427 (0.516)	3.044 (0.087)	14.620 (< 0.000)	0.34
CMJ (w/o arm swing/m)	35.6[bcyz] (6.9)	26.7[ax] (5.7)	26.4[ax] (5.2)	10.179 (< 0.001)	0.26	0.156 (0.694)	8.072 (0.006)	10.076 (< 0.000)	0.26
CMJ (w/arm swing/m)	41.6[bcyz] (6.1)	34.3[ax] (6.1)	32.1[ax] (6.6)	8.118 (< 0.001)	0.22	1.751 (0.191)	4.907 (0.031)	7.301 (0.002)	0.21
Motor Coordination Characteristics				**3.933 (< 0.001)**	**0.17**	**0.010 (0.999)**	**3.077 (0.035)**	**3.697 (0.002)**	**0.17**
Jumping Sideways (2*(n/15s))	103[bcyz] (13.0)	88[acx] (15.0)	78[axy] (11.0)	12.269 (< 0.001)	0.29	0.031 (0.860)	8.747 (0.005)	11.323 (< 0.000)	0.28
Moving Sideways (2*(n/20s))	69[bcz] (13.0)	59[a] (9.0)	55[ax] (10.0)	5.860 (0.005)	0.16	0.014 (0.906)	4.878 (0.031)	4.131 (0.021)	0.12
Balance Beams (3*n)	59 (10.0)	54 (10.8)	50 (12.7)	2.249 (0.115)	0.07	1.124 (0.294)	1.124 (0.294)	1.338 (0.271)	0.04

TABLE 2. Continue.

	Elite Mean (SD) (N = 10)	Sub-elite Mean (SD) (N = 24)	Novice Mean (SD) (N = 27)	MANOVA [F(p)]	Effect Size Partial Eta Squared	Covariate Maturity Offset [F(p)]	Covariate Age [F(p)]	MANCOVA [F(p)]	Effect Size Partial Eta Squared
Psychological Characteristics				**1.669 (0.075)**	**0.19**	**0.825 (0.572)**	**0.787 (0.601)**	**1.416 (0.162)**	**0.18**
ARTF	5.84 (1.3)	6.24 (1.4)	6.50 (1.7)	0.680 (0.511)	0.02	1.899 (0.174)	0.385 (0.538)	0.365 (0.696)	0.01
Imagery	5.68 (0.9)	5.20 (1.2)	4.97 (1.4)	1.099 (0.341)	0.04	0.655 (0.422)	2.093 (0.154)	1.515 (0.230)	0.05
SDCM	5.91 (1.1)	6.27 (3.6)	5.35 (1.2)	0.883 (0.420)	0.03	0.822 (0.369)	0.000 (0.997)	1.118 (0.335)	0.04
Perfectionism	5.64[bcyz] (1.5)	3.87[x] (1.2)	3.83[ax] (1.4)	6.934 (0.000)	0.20	1.482 (0.229)	0.372 (0.544)	4.800 (0.012)	0.15
SUSS	6.46 (1.8)	7.05 (1.3)	6.75 (1.3)	0.644 (0.530)	0.02	0.005 (0.946)	1.034 (0.314)	0.513 (0.601)	0.02
Active Coping	6.50 (1.2)	6.29 (1.2)	5.69 (1.3)	2.082 (0.140)	0.07	0.606 (0.440)	1.496 (0.227)	2.558 (0.087)	0.09
Clinical Indicators	6.48 (1.4)	7.42 (1.4)	6.99 (1.2)	1.739 (0.180)	0.06	2.476 (0.122)	1.341 (0.252)	0.778 (0.465)	0.03

Elite = a, Sub-elite = b, Novice = c, Covariates for elite, sub-elite and novices: Elite = x, Sub-elite = y, Novice = z ; ARTF = Adverse Response to Failure; SDCM = Self-Directed Control and Management ; SUSS = Seeking and Using Social Support

TABLE 3.

Variable	Individual Score (Elite)	Elite Average	Novice Average
Height (cm)	185.60	175.81	168.12
Weight (kg)	81.90	65.72	56.72
Sitting Height (cm)	96.1	829.90	2164.02
Fat %	15.90	11.56	13.35
BMI (kg/m^2)	23.78	21.11	16.71
Sit and Reach (cm)	36.5	24.85	16.78
Knee push ups (n/30s)	30	35.70	29.76
Sit ups (n/30s)	35	35.40	32.64
Standing broad jump (cm)	225	220.80	185.00
Shuttle run (s)	19.37	15.79	20.27
Sprint (5m) (s)	1.09	1.19	1.24
Sprint (10m) (s)	1.77	1.95	2.08
Sprint (20m) (s)	2.97	3.27	3.59
Sprint (30m) (s)	4.15	4.56	5.10
ESHR (m)	10.5	11.75	7.26
CMJ (w/o arm swing/m)	35.2	35.62	26.53
CMJ (with arm swing/m)	42.8	41.64	32.20
Jumping sideways (2*(n/15s))	88	103.10	79.20
Moving sideways (2*(n/20s))	58	69.00	56.72
Balance beam (3*n)	54	59.00	50.96
Adverse response to failure	6.38	5.84	6.46
Imagery	5.73	5.68	5.02
SDCM	7.14	5.91	5.34
Perfectionistic Tend.	5.40	5.64	3.90
SUSS	8.22	6.46	6.77
Active coping	7.40	6.50	5.72
Clinical Ind.	8.67	6.48	7.00

DISCUSSION

The aim of this research was to provide benchmarks for the anthropometric, physical performance, motor coordinative, and psychological characteristics amongst elite, sub-elite and novice badminton players and participants in Flanders, Belgium. A non-sport specific test battery showed that youth elite badminton players outperform peers of lower skill levels on anthropometry, physical performance, motor coordination, and psychological profile. The study shows that through the use of a talent identification test battery, it is able to identify and distinguish the top performers.

Anthropometry

The increase in BMI with increasing skill level was the most significant finding among the anthropometric variables, resulting in the elite players having a significantly higher BMI than sub-elite players and novices. It is plausible that a high BMI is representative of a more dominant muscular component in badminton players rather than adiposity, which is supported by the absence of differences in fat percentage. It should be noted that in this study muscle mass was not directly measured to corroborate this explanation. Fat percentages in our study are comparable to data in other studies, although in slightly older populations (e.g. 10–14% in junior males and females) [4]. Other studies posited that badminton players are generally tall and lean with an ectomesomorphic body type suited to the high physiological demands of a match [4]. This interpretation is also supported by the differences in physical performance variables. Although it is advantageous to possess a tall stature for badminton success, as it contributes to the ability to reach and cover more of the court [7], we did not perform analyses at an individual level, and thus this was not corroborated by our findings. There are in fact a multitude of factors that enable court coverage, and stature is not a critical determinant of success in badminton [46].

Physical performance

Elite youth players exhibited better scores on most of the physical performance tests, especially flexibility, endurance, lower body speed and explosive power. In all of the tests related to the explosive component, absolute scores were better in elites although they did not all reach statistical significance. Badminton players tend to rely on their flexibility for execution of lunges towards the net and for execution of difficult low, fast approaching shots that often require some upper body shifting and bending. In the jumps means for elites were significantly higher than other groups. This finding aligns well with the explosive characteristic that is required for elite badminton athletes. Badminton places a great demand on explosive power [3]. An explosive player will typically be able to jump high, change direction quickly and will generally appear to be swift and mobile on the badminton court, due to ability to combine coordination and muscular properties [3]. Recent research has shown that coaches consider explosive power as a crucial characteristic of elite players, as they more frequently utilise high vertical jumps throughout matches when executing power smashes, which allows them to sometimes jump to a height that places their hip at the top of the 1.524 m high net [47]. Throughout the years high jump smashes have become more frequent amongst elites, as it is an effective form of attack. Likewise in endurance, elites outperformed their lower-ranked counterparts. The intermittent actions of badminton employ the use of the aerobic and anaerobic systems, with 60–70% belonging to the aerobic system [4]. The importance and necessity of being physically fit is of utmost importance to an elite as competitive matches last 40–60 minutes, with a mean rally time of approximately 8 seconds and a mean resting time of approximately 15 seconds [4].

Although sprint scores tended to improve with increasing skill level, no significant differences were observed in the 5, 10, 20, or 30 m tests after controlling for age and maturity effects. In contrast, the 5 meter shuttle run as a measure of speed and change of direction ability did discriminate between groups. In this change of direction ability test, elites outperformed novices by 28%. These findings are in line with the conflicting results in the literature with respect to sprint tests (7). Previous badminton studies have not shown differences between groups when the 30 m sprint was repeated with a demographic of elite, sub-elite and non-players, but the elites were significantly faster in a badminton-specific speed test [48]. It can be suggested that classic sprint tests are less fit to discriminate between different skill levels in badminton compared to speed and change of direction ability tests like the shuttle run.

Motor coordination

While the shuttle run test involves some aspects of motor coordination, strong effects of skill group occurred in the motor coordination tests. An explosive player will generally have better change of direction ability and badminton players need good balance and agility during rapid postural actions on the court [49]. Indeed the effects were most prominent in the coordination tests that are performed under time pressure, as is the case during the badminton game. The relevance of possessing good coordinative skills in general and for sport participation should not be underestimated, as children with low levels of motor coordination will probably lack fundamental movement skills or will be less proficient [39]. This finding is in line with other studies showing that general motor coordination is related to skill level in many sports, and that athletes with better general motor coordination show steeper progression curves [10]. In the field of practice it could be useful for coaches to include motor learning tests in selection procedures, as objective criteria that could discriminate between elite and sub-elite pre- adolescent gymnasts [12]. Moreover, the inclusion of tests previously mentioned also extend further by inclusion into training programmes, as more attention should be placed on the development of general motor coordination, especially as it relates to young athletes.

Psychological characteristics

Elite athletes scored considerably higher than sub-elite athletes and novice participants in perfectionistic tendencies. Perfectionism in sport is not uncommon and is defined as a multidimensional personality disposition or trait that influences cognitive, emotional, and behavioural functioning in athletes [50].

In sport, perfectionism is usually characterised by very high performance standards along with the tendency to engage in overly critical self-evaluations [51, 52]. The mentioned traits of perfectionism align well with the characteristics that an elite would possess. Similarly in other racquet sports such as table tennis, a study on elites reflected that high scores in perfectionism point to a quality-driven and detail-oriented personality [15]. The high scores on perseverance and perfectionism among table tennis elites also reflect the requirements for developing well-honed skills in table tennis [15]. Elites are constantly faced with many stressful and demanding situations, as they spend countless hours in weekly training and competition. Sport is associated with numerous stressful demands such as performance difficulties, injuries, interpersonal conflict, and organizational level conflicts [53]. Consequently, successful adaptation in high level sport requires athletes to constantly set and strive for high performance goals, learn new skill repertoires, minimise mistakes, and manage emotions and dysfunctional cognitions [54, 55]. Perfectionism has been associated with individual differences in stress and related outcomes such as burnout, psychological distress, and emotions in various contexts [51, 56, 57]. Such factors are quite common, as elite athletes are faced with constant pressure and demands to perform and produce results at high levels. Some studies have shown that there can be a positive relationship between perfectionism and sport, by demonstrating that contextual motivation to participate in sport was also related to situational coping during a sport competition [58]. There is evidence that motivation plays a mediating role in the relationship between perfectionism and coping [59].

Discriminant analysis

The excellent results of the discriminant analysis allow us to appreciate the combined value of the domains of anthropometry, physical performance, motor coordination, and psychological traits to reveal how different expert athletes are from their lower-level peers. These characteristics may help to discriminate between groups, and use of a multifactorial battery with an additional psychological component is a good aid in accomplishing such. The stability of the classification procedure was checked by a cross-validation run.

In the cross-validated discriminant analysis, eleven athletes were incorrectly classified, with the most remarkable case being an elite player being classified as a novice. Closer inspection of this participant revealed a higher body weight and lower motor coordination scores compared to the other elite players, and a greater body height. While the former may not be beneficial to badminton performance, being taller and having longer limbs is considered an advantage with respect to covering ground during the game. This case of misclassification supports the compensation phenomenon [60], but might also be explained by the absence of other factors in this study, for example badminton-specific tests for techniques or tactics.

The significance of TID programmes, based upon adequate reference values, is growing as many racquet sport associations use talent development programmes to help young, non-elite players to develop into elite players [1]. For badminton more specifically, TID assessments are being used to help [61] with the growth and understanding of what the needs for players are. Studies such as Gao's [61] have also looked into the impact of talent identification and development programmes for badminton. This research highlighted the differences in the application of TID in China and the UK and factors such as its impact on athlete's developmental opportunities, differences in the identification of badminton talent progress and in player development, and also at which age players specialise in badminton and when they reach their peak performance [61]. The results showed significant differences in the application of TID from both organisations. Although both share the same goal of securing medals at major championships, China's programme is more rigid and structured and the UK's is far more fluid and has more wide-ranging development aspirations. It was noted, however, that both approaches to TID have their merits [61]. Such studies are indicative of a growing need for interest in the effects of TID in the sport of badminton, as more and more countries crave the knowledge and success of the bigger countries.

CONCLUSIONS

Use of a non-specific, multifactorial battery resulted in benchmarks for youth badminton players of different levels, and add to the current understanding of the profile of badminton athletes. Characteristics in the domains of speed, explosive power, coordination, endurance and psychology, subserving badminton performance, were better in higher ranked players. The use of such a multifactorial test battery might help coaches in crucial stages in the young athlete's career (selection or identification), and in the monitoring of his/her athletic development. Coaches can use these data as a means of having a more objective perspective for selection purposes. The TID test battery used in this research can be quite helpful for coaches and organisations as it provides a more cost-effective manner in which to achieve talent-oriented results. Many smaller countries or countries with smaller populations and lack of funding for TID can use this test battery, as it is mostly composed of inexpensive materials for testing. There is also a chance at talent transfer opportunities for other racquet sports that usually are less popular sports. Furthermore, many of the tests used in this research could also lead to similar results in other racquet sports. Racquet sports have been known to possess many similarities with regards to their physiology, nutrition, notational analysis, etc. [5], which means that knowledge from one sport can assist in another. This was also reflected in the work of Robertson et al. [47] when surveys questioning coaches from different racquet sports (table tennis, tennis and badminton) were able to identify the importance and value of testing an assortment of skill components. Nevertheless, the knowledge of the physical and mental skills can be an instrumental tool used to identify athletes prior to having any technical or tactical feedback.

Limitations and directions for future research

This study revealed clear skill-related differences between youth badminton players in the areas of anthropometry, physical performance, motor coordination, and psychological profiles. The combination of these factors allowed an excellent classification of the participants to their skill group. However, it must be acknowledged that some limitations apply to this study. Apart from the relatively low sample sizes, which are inherent to this type of research, the cross-sectional approach did not allow conclusions with respect to causality. From this point of view, detailed documentation of individual training history and the continuation of this research with the aim of a longitudinal analysis are advised.

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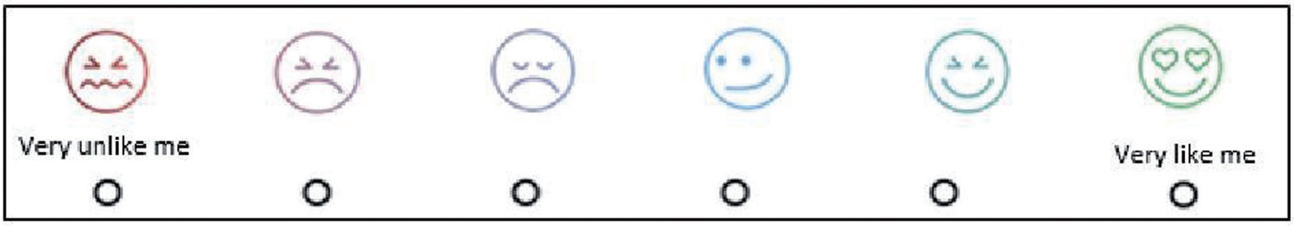
APPENDIX 1. Questionnaire

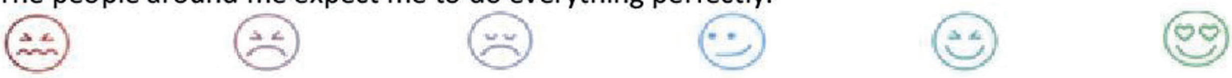
NAME: ____

DATE OF BIRTH: ____________________________________



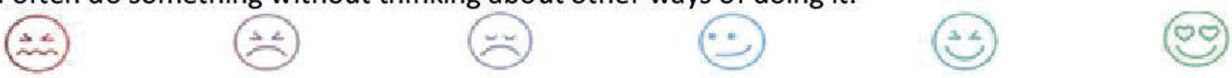
1. I often ask advice from different people.

2. The people around me expect me to do everything perfectly.

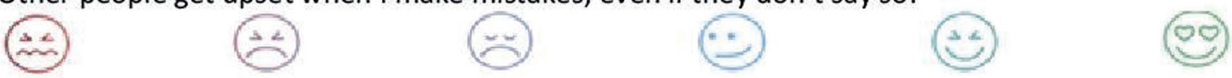


3. When things don't work out for me I have doubts about my future.

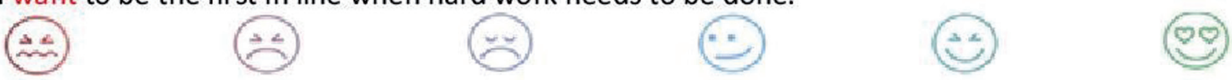
4. I often do something without thinking about other ways of doing it.



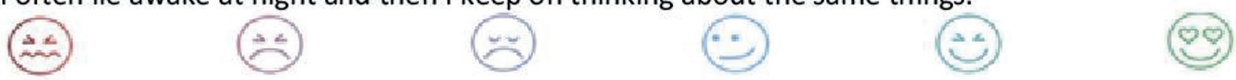
5. Other people get upset when I make mistakes, even if they don't say so.



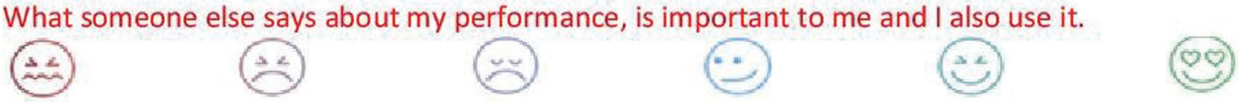
6. I want to be the first in line when hard work needs to be done.



7. I often lie awake at night and then I keep on thinking about the same things.

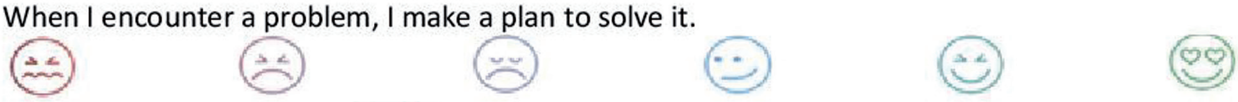


8. What someone else says about my performance, is important to me and I also use it.



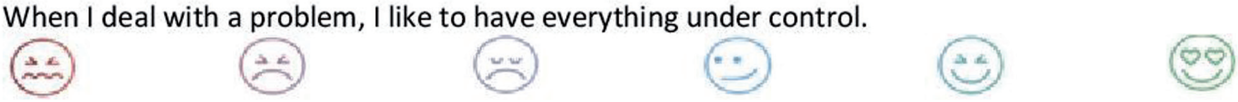
9. When I prepare, I use imagery.

10. When I encounter a problem, I make a plan to solve it.



11. I know who to go to when I need something.

12. When I deal with a problem, I like to have everything under control.



13. When I have eaten something I sometimes feel guilty because eating changes my body shape.

14. I can deal with anything I run into.

15. I use imagery to improve my performance.

16. I can adapt and change myself when something is not going well for me.

17. Daily problems can often make me feel sad.

18. I happily ask others to help me.

19. I often have too little energy.

20. My preparation for a competition or a performance always has to be exactly the same.

21. My sleep is often disturbed by the troubles in my head.

22. Even small setbacks make me lose my attention.

23. I have a well thought-out plan to become an elite athlete.

24. I imagine how I would deal with setbacks.

25. I regularly imagine what it feels like to have a good performance.

26. When I don't know something, I look for someone who does.

27. Sometimes I don't succeed in something. I hate it that I cannot control that.

28. I am often worried that bad things will happen.

29. My life is well-organised.

30. I give myself treats, even if I haven't reached a goal.

31. People say about me that I am good at following plans I have made for myself.

32. I regularly come to an agreement with myself about what exactly I want to achieve.

33. I like to try things out in my head first.

34. When I don't succeed in something, I think that people won't be interested in me anymore.

35. I sometimes forget to put items of my equipment in my sports bag.

36. I think that asking someone else for help is a sign of weakness.

37. I often keep on thinking about mistakes I have made. Hence/Therefore I do my performance not so well.

38. I am worried that I am getting too heavy.

39. I usually blame a failure on other people or circumstances.

40. If I am nervous, I find it difficult to overcome this feeling when I am performing.

41. If I don't spend all my time and attention on my sport, my performance won't be as good.

42. If something goes wrong I think it is hard to see how to continue afterwards.

43. I only feel happy when I win.

44. I repeat my routine in my head so that I really know what to pay attention to.

45. I often find it difficult to talk to other people about things that are bothering me.

46. When things are not going well, I am worried about what other people will think.

47. I am lazy.

48. If something unexpected happens it is very hard for me to adapt myself to that.

49. I think it's hard to convince myself to overcome problems.

50. I am good at resisting temptations.

51. When I have a problem, I don't have anyone I can turn to for help.

52. If I make a mistake I dwell on it and can't see the big picture.

53. I socialise with my teammates much less than I used to.

54. I often do things I know I'd better not do.

55. I can't hang out with people who do not want to strive forward.

56. Failures do not distract me from my pathway to success in my sport.

57. I can clearly see how I have to become an elite athlete.

58. I take time to make clear what has been asked.

59. I often forget appointments or timings.

60. When I fail, people are less interested in me.

61. Usually I don't worry a lot.

62. My teammates would describe me as someone who is always the same.

63. I am someone who runs through things over and over again in my head.

64. Before I start a routine I imagine executing it.

65. How my practice or competition went determines how I feel.

66. I tackle setbacks.

67. I wish I had more discipline.

68. Every training session I go through my routines in my head as well.

69. Compared to my teammates I succeed less often in completing a heavy training session.

70. When something looks really bad, I still keep on going.

71. I find it difficult to get myself enthusiastic/motivated.

72. When I don't succeed in something I am mostly worried about what others will think about me.

73. I am not interested anymore in often hanging out with my trainings group.

74. I prepare well for each training session.

75. I often feel nervous.

76. I get annoyed very easily.

77. I am more often tired and weak than my teammates.

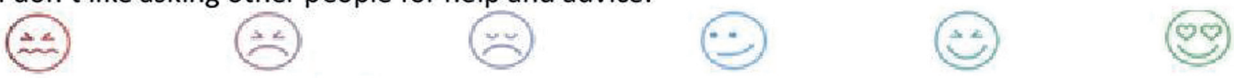
78. Before I arrive at the competition I already go through what I am supposed to do during the competition in my head.

79. I sometimes feel unhappy without really knowing why.

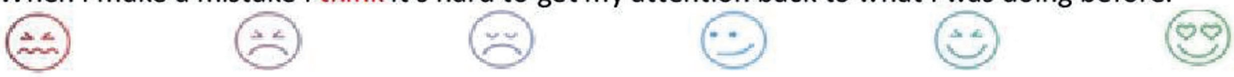
80. When I have to do a something I worry about, I imagine what I can do to conquer that feeling and to perform successfully.

81. When I have a bad practice or competition, the people I consider important are often disappointed in me.

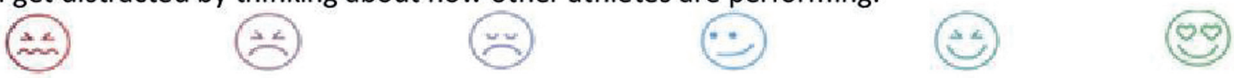
82. I don't like asking other people for help and advice.



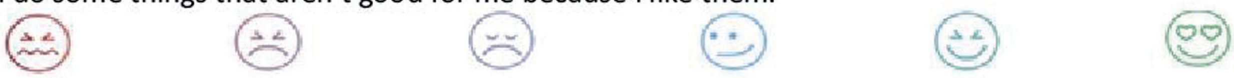
83. When I make a mistake I think it's hard to get my attention back to what I was doing before.



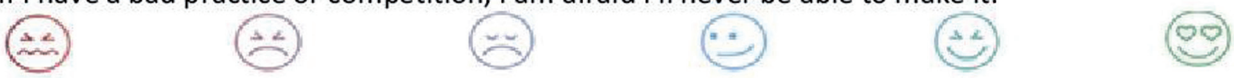
84. I get distracted by thinking about how other athletes are performing.



85. I do some things that aren't good for me because I like them.



86. If I have a bad practice or competition, I am afraid I'll never be able to make it.



87. I find it difficult to stop bad habits.