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ORIGINAL ARTICLE

A multidisciplinary approach of success in team-handball

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Abstract The aims of this study were: (i) to describe and compare morphologic, physiological, specific-skills and psychological attributes of team-handball players from two teams with different performances, and (ii) to identify the variables that differentiated between the successful and less-successful team-handball players. Thirty-four (age 23.4 ± 4.7 years; stature, 182 ± 6.3 cm; body mass 85.4 ± 11.4 kg) professional male adult team-handball players were studied. Eighteen athletes (age 23.0 ± 3.8 years) were classified as successful, and sixteen athletes (age 23.8 ± 5.5 years) were classified as less-successful. Each participant was measured according to four categories of variables, i.e. morphologic (proportionality, somatotype and body composition), physiological, handball-specific skills (technical skills and game intelligence profile) and psychological profiles. Each set of data was analyzed using MANOVA (for which success was the between participant variable), ANOVA and a discriminant function analysis (Stepwise method). Finally the selected measures were analyzed together (a multidisciplinary approach) using a discriminant function analysis (Stepwise method) to determine which combination of measures best discriminated between the two groups of success. The results showed that: (1) the two groups presented significant results for 10 of 77 variables; (2) six measures (30-m sprint, standing vertical jump, right handgrip, sit-ups, stature and ability to vary their actions) appear to be the strongest predictors of success in team-handball (Successful = −1.827; Less-successful = 2.055; $\Lambda = 0.200$, $\chi^2(6) = 46.603$, $P < 0.001$). The chosen variables are representative of three different categories (morphologic, physiological and team-handball-specific skills) showing that the study of modern team-handball requires a multidisciplinary approach.

PALABRAS CLAVE
Balonmano;
Morfología;
Fisiología;
Psicología;
Habilidades

Enfoque multi-disciplinar en un equipo de balonmano

Resumen Los objetivos de este estudio fueron: (i) describir y comparar las características morfológicas, fisiológicas, específicas y psicológicas de los jugadores de balonmano pertenecientes a dos equipos con diferentes rendimientos, y (ii) identificar las variables diferenciadoras entre los jugadores de los equipos de balonmano exitosos y menos exitosos. Se estudió a treinta y cuatro

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jugadores adultos profesionales de balonmano (edad, 23,4 ± 4,7 años; estatura, 182 ± 6,3 cm; masa corporal 85,4 ± 11,4 kg). Se clasificó a dieciocho atletas como exitosos (edad, 23,0 ± 3,8 años), y a dieciséis atletas como menos exitosos (edad, 23,8 ± 5,5 años). Se midió a cada participante dependiendo de cuatro categorías de variables: morfológicas (proporcionalidad, somatotipo y composición corporal), fisiológicas, habilidades específicas del balonmano (habilidades técnicas y perfil de inteligencia de juego) y perfiles fisiológicos. Se analizó cada conjunto de datos utilizando MANOVA (siendo el éxito la variable entre participantes), ANOVA, y un análisis de función discriminante (método Stepwise). Finalmente se analizaron conjuntamente las mediciones seleccionadas (enfoque multidisciplinar) utilizando un análisis de función discriminante (método Stepwise) para determinar qué combinación de mediciones discriminaba mejor entre los dos grupos de éxito. Los resultados reflejaron que: (1) los dos grupos presentaron resultados significativos para 10 de las 77 variables; (2) seis mediciones (sprint de 30 m, salto vertical de pie, fuerza en la mano derecha, ejercicios abdominales, estatura y habilidad para variar acciones) parecen ser los mejores pronosticadores del éxito en los equipos de balonmano (Exitosos = −1,827; Menos exitosos = 2,055; Λ = 0,200, X2(6) = 46,603, P < 0,001). Las variables seleccionadas son representativas de tres categorías diferentes (morfológica, fisiológica y habilidades específicas del balonmano), lo que refleja que el estudio de los equipos modernos de balonmano requiere un enfoque multidisciplinar.

Introduction

One of the most fundamental steps in any multistep sport program is to evaluate the player's performance, within different areas.[1] Nevertheless, in team sports, performance is not simple to measure[2] and selection is known to be as a complex process (often unstructured).[3] In fact, the literature relations to sports expertise, has tended to be mono-disciplinary.

In team-handball, the study of the morphologic profile of successful athletes has been one of the issues most often addressed, and the differences between players from teams exhibiting different levels of performance[4] are one of the main areas of study.

Also the physiology of team-handball (and fitness) is now better understood,[5,6] and it is known that modern team-handball incorporate acyclical patterns of movement (the intensity of exercises varies in a relatively unpredictable manner).[7]

About the interaction between expertise and individual movement patterns, it seems that random variability characterizes less experienced motor performance, whereas active functional variability may demonstrate expert motor performance.[8] In other words, it seems that movement frequency rate (which is associated with the ability of ball manipulation) may significantly predict team-handball players' performance.[9] Nevertheless, the choice and the frequency of using a particular tactical option in attack did not guarantee efficiency (to score), and could be affected by the level of individual technical-tactical skills in low-quality teams.[10] These findings suggested that the team-handball-specific skill evaluation could be useful as a selection indicator.[3]

In addition, the sport psychology literature, based on the idea that psychological attributes can contribute to athletic success, has incorporated since its inception, a great interest in the study of excellence.[11] It seems that motivation,[12] anxiety management and coping skills[13] may play an important role in athletic development, but it is still difficult to determine strong psychological differences between elite athletes and their less successful counterparts.[14]

However, to move forward in the understanding of expertise a more multidisciplinary approach is needed. In accordance, we hypothesized that significant differences could be found among performance groups and the purposes of the present study were: (i) to describe and compare morphological, physiological, specific-skills and psychological attributes of team-handball players from two teams with different performances, and (ii) to identify the variables that differentiated between the successful and less-successful team-handball players.

Methods

Study procedure and subjects

Thirteen teams participated in the National Handball Professional Championship. A total of thirty-four team-handball players (age 23.4 ± 4.7 years), from two teams ranked (during the 1st half of the National Championship), i.e. (i) first (Successful; n = 18; age, 23.0 ± 3.8 years), and (ii) last place (i.e. thirteenth) (Less-Successful, n = 16, age 23.8 ± 5.6 years), were studied. The local Scientific and Ethical committees approved the experimental protocol. Before inclusion in the study, the objectives and procedures were explained to subjects, and written informed consent was obtained from them. All participants were tested during the competitive period, and measurements of each participant were undertaken according to four categories of variables, namely: morphological (proportionality, somatotype and body composition), physiological, team-handball-specific skills (technical skills and game intelligence) and psychological profiling.

Morphologic profiling

A total of thirty-three anthropometric dimensions were obtained. The dimensions included five basic measures, nine skinfolds (mm), eight girths (cm), six breadths (cm) and five lengths (cm). The five basic measures were stature (cm), body mass (kg), sitting height (cm), armspan (cm), handspan (cm). The nine skinfolds were subscapular, triceps, biceps, chest, midaxillary, iliac crest, abdominal, front thigh and medial calf. The eight girths were head, arm (relaxed), arm (flexed and tensed), forearm (maximum), chest (mesosternale), waist (minimum), thigh (mid-troch-tib. lat.) and calf (maximum). The six bone breadths were biacromial, transverse chest, A–P chest depth, biiliocristal, humerus and femur. The five lengths were acromiale-dactylion, acromiale-radiale, radiale-stylion, radiale-dactylion and midstylion-dactylion. Measurements included in the anthropometric profile were obtained following the protocol in Marfell-Jones et al.,[15] with the exception of armspan (perpendicular distance between the longitudinal planes of the left and right dactyilon), handspan (the greater distance between the longitudinal planes of the 1st and 5th fingers), chest skinfold (the skinfold measurement was taken obliquely in the mean distance between the breast nipple and the axilla fold), midaxillary (measured horizontally in the level of xiphoid-sternal articulation over the midaxillary line), acromiale-dactylion length (the linear distance between the acromiale and dactylion sites) and radiale-dactylion length (the linear distance between the radiale and dactylion sites). Anthropometric measurements were obtained using portable measurement devices. Stature and heights were measured without shoes and head-covers, using a portable Anthropometer (GPM, Siber-Hegner, Zurich, Switzerland, 2008) calibrated to the nearest 0.1 cm. Body mass was measured with subjects wearing light clothing and without shoes, to the nearest 0.5 kg, using a scale (Secca model 761 7019009, Vogel & Halke, Hamburg, Germany, 2006) calibrated with known weights. Skinfold thickness was obtained using a skinfold caliper (Slim Guide, Rosscraft, Surrey, Canada, 2001), lengths and diameters using a large sliding caliper (GPM, Siber-Hegner, Zurich, Switzerland, 2008), girths using a flexible non-stretching steel (Model W606PM, Lufkin, TX, USA). All measures were collected by two technicians accredited by the International Society for the Advancement of Kinanthropometry (ISAK) with the levels 1 and 2 (the intra-observer technical errors of measurements were well below the accepted maximum for stature, skinfolds, breadths and girths). Measurements were gathered and used to evaluate proportionality, somatotype and body composition. The somatotype was determined according to Head-Carter anthropometric protocol[16] and to evaluate body composition, the fractionation of body mass in five components (skin, adipose, bone, muscle and residual tissue masses) was used.[17]

Physiological profiling

Before the physiological tests, performed a 20-min warm-up (incorporating a slow jog followed by static and dynamic stretching) prior to, and rested during the 10-min between tests (recovery period). Water breaks and extra rest time were allowed if needed. Each athlete was instructed and verbally encouraged to give his maximal effort.

Participants performed nine tests and fourteen variables were recorded for analysis. These included two speed tests: 30-m sprint and agility.[18] All sprint times were recorded using electronic timing lights (Wireless Sprint System, BROWER Timing Systems, Salt Lake City, UT, USA) and the best scores (time; in s) were recorded for analysis. To determine lower body explosive strength, as reported in Bosco et al. protocol,[19] the athletes performed four different vertical jumps (squat jump; countermovement jump; Abalakov jump; drop jump – 40 cm) on an Ergojump (Digitime 1000, Digitest, Jyvaskyla, Finland). Three trials were performed and the best trial was recorded for analysis (in m). To complement the aforesaid tests to determine the upper body explosive strength, the athletes performed three trials of two vertical jumps adapted to arms (i.e. squat jump adapted to arms; countermovement jump adapted to arms). To measure handgrip strength, the participants completed three trials (with each hand; in kgf), on a grip strength dynamometer (Jamar Hidraulic Hand Dynamometer, Sammons Preston, Bolingbrook, IL, USA).[18] To measure back strength the participants completed three trials on a back muscle dynamometer (Takei n°1858, Tokyo, Japan).[18] In all dynamometry measures, the best scores were recorded for analysis (in kgf). The abdominal strength (i.e. endurance) was assessed using the sit-up test (in 60 s), and the number of executions was recorded for analysis (#).[18] To study the aerobic capacity, the participants performed the Cooper test[18] and the estimated VO_{2max} values ($R = 0.90$) were calculated using the Cooper test equation [$VO_{2max} = 22.351 \times$ (distance; in m)/1000) $- 11.288$].[20] To perform the Back-Saver Sit-and-Reach test, the participants completed three trials on a flex tester (AcuFlex, Novel Products Inc, Addison, IL, USA), as reported by the Cooper Institute for Aerobics Research.[21] The best score was recorded for analysis (in cm).

Team-handball-specific skills profile

According to Massuça et al. (in press), the scientific literature does not include validated tools to assess the technical and tactical proficiency of team-handball athletes. To achieve this purpose, two handball expert coaches evaluated (on a five-points Likert scale ranging from ''very poor'' – 1 to ''excellent'' – 5), during 2 training sessions, all participants using the grid suggested by Moreno,[22] i.e.: (i) seven motor/technical skills dimensions (defensive displacements; types of marking; ability to retrieve balls; ability to escape the opponent; pass and reception; type of shots; one vs one); and (ii) four cognitive and game intelligence dimensions (ability to create and fill up spaces; offensive and defensive battle; defensive collaboration; ability to vary their actions).

Psychological profiling

All participants completed three psychological tests: (i) Task and Ego Orientation in Sport Questionnaire – TEOSQ; (ii) Sport Competition Anxiety Test - SCAT; and (iii) Inventory of Self-Perception – ICAC.

The TEOSQ, a trait-based version of Duda,[23] provided a measure of motivational orientation. The exploratory factor analysis done, with a subsample of adult male handball athletes (n = 203) from the Portuguese (European) cultural context, supported: (i) the hypothesized theoretical model of two factors (Bartlett's Test of Sphericity: χ^2 = 628.992, df = 78, P < 0.001; KMO = 0.754; GFI = 0.927; AGFI = 0.874; RMSR* = 0.040), and (ii) a satisfactory internal consistency (Cronbach's alpha coefficients being 0.70 and 0.77 for the task and ego orientation subscales, respectively). Subjects must respond to 13 items concerning success in sport, which are preceded by the statement ''I feel most successful in sport. Responses to each item are measured on a five-point Likert scale ranging from ''strongly disagree''[1] to ''strongly agree''[5] and the intensity of agreement or disagreement with each item reflects: or a possible task orientation (e.g. ''I learn a new skill by trying hard'') or an ego orientation (e.g. ''I can do better than my team mates''). Both, task and ego orientations were calculated.

The SCAT is a 15-item scale that is used to measure competitive trait anxiety in adults. Ten of the above mention items make up the scale; five are spurious items (1, 4, 7, 10, and 13) included solely to reduce response bias. Items are measured on a 3-point scale, from ''Hardly Ever''[1] to ''Often''.[3] Scores range from 10 to 30, and higher scores indicate higher competitive trait anxiety. Sample items include, e.g. ''Before I compete I worry about not performing well'' and ''Before I compete I get a queasy feeling in my stomach''. The psychometric properties of this scale have been extensively evaluated.[24] Item-total correlations range from 0.60 to 0.82. Internal consistency ranges from 0.95 to 0.97 and mean test-retest reliability is 0.77. Martens et al.[24] reported that high SCAT scores were related to high competitive state anxiety in competitive situations and that SCAT scores predicted competitive state anxiety better than coaches' ratings.

The ICAC is a subjective scale of self-assessment. To fill the scale subjects must respond to 20 items concerning self-perception. Responses to each item are measured on a five-point Likert scale ranging from ''Disagree''[1] to ''Very much agree''.[5] Higher scores indicate higher self-concept. According to Vaz-Serra,[25] this instrument has good internal consistency (Spearman–Brown coefficient = 0.791 for a sample of 920 participants) and high temporal stability (test–retest = 0.838, for an interval of 4 weeks). An exploratory factor analysis supports the theoretical model of six factors[25]: (i) Social acceptance/rejection (e.g. ''I'm usually well accepted by others''; α = 0.76); (ii) Self-efficacy (e.g. ''I often give up my job when I meet difficulties''; α = 0.70); (iii) Psychological maturity (e.g. ''Tend to be frank and express my opinions''; α = 0.72); (iv) Impulsivity-activity (e.g. ''I am a person who really like doing what I want''; α = 0.71). However, because the fifth and sixth factors had a mixed nature[23] were not considered in this study.

Statistical treatment

All calculations were performed using the Statistical Package for the Social Sciences (SPSS Inc, version 17.0, Chicago, Illinois). Descriptive and comparative data are presented, and group data are expressed as mean and standard deviation (SD) for all dependent variables. Variables were checked for normality. Successful and Less-Successful groups were compared on each variable of interest using multivariate (Non-Parametric MANOVA) and univariate (Non-Parametric ANOVA) analysis of variance. The stepwise discriminant function analysis was used for all data sets to determine which combination of measures best discriminated between the two groups of players. Finally, in a multidisciplinary approach, all selected variables were analyzed together, using the stepwise discriminant function, to determine which combination of measures best discriminated between the two groups of success. For all analyses, 5% was adopted as the significance level.

Results

As previously mentioned, measurements for each participant were undertaken within to four categories, i.e. morphological, physiological, handball-specific skills and psychological profile, related variables.

Morphological profile

No significant differences were indicated, using MANOVA, in anthropometric measures (Λ = 0.06, $F_{31,2}$ = 9.948) and specially as regards girth measures (Λ = 0.776, $F_{8,25}$ = 0.901) and breath mesures (Λ = 0.789, $F_{6,27}$ = 1.205). However, the MANOVA showed significant difference between groups in what concerns basic measures (Λ = 0.614, $F_{4,29}$ = 4.563, P < 0.01), skinfolds measures (Λ = 0.348, $F_{9,24}$ = 4.995, P < 0.01) and length measures (Λ = 0.714, $F_{4,29}$ = 2.903, P < 0.05). ANOVA showed significant differences between groups in stature, sitting height and suprailiac skinfold. Discriminant analysis showed that a combination of five variables could successfully discriminated between groups (coefficient: stature = −1.738; chest skinfold = −1.740; iliac crest skinfold = 1.005; biiliocristal breath = 1.234; radiale-dactylion length = 1.514). The described function (Λ = 0.165, $\chi^2(5)$ = 53.080, P < 0.001) explained 100% of anthropometric variance. MANOVA showed significant differences in somatotype components (Λ = 0.763, $F_{3,30}$ = 3.108, P < 0.05) specificaly in endomorphy (ANOVA). In fact, discriminant analysis showed that endomorphy (coefficient = 1.000) successfully discriminated the two groups; 61.8% of original grouped cases were correctly classified (Λ = 0.830, $\chi^2(1)$ = 5.886, P < 0.05). Nevertheless, no significant differences were observed in the study of body composition (Λ = 0.752, $F_{5,28}$ = 1.846) (Table 1).

Physiological profile

The MANOVA showed significant groups difference on physiological characteristics (Λ = 0.306, $F_{14,19}$ = 3.085, P < 0.05).

Table 1 Descriptive statistics of morphological characteristics (proportionality, somatotype and body composition) for Successful and Less-Successful team-handball groups (mean (SD)), and independent samples comparisons.

	Successful	Less-Successful	*F*	*P-Value*	
Stature (cm)	184.57 (5.62)	179.11 (5.98)	7.505	0.010	*
Body mass (kg)	84.94 (9.25)	85.91 (13.70)	0.059	0.809	NS
Sitting height (cm)	95.69 (3.19)	91.71 (3.31)	12.704	0.001	**
Handspan (cm)	22.81 (1.27)	23.19 (2.05)	0.401	0.531	NS
Armspan (cm)	190.38 (6.39)	190.72 (7.41)	0.021	0.886	NS
Subscapular skinfold (mm)	11.03 (4.64)	14.41 (6.39)	3.166	0.085	NS
Triceps skinfold (mm)	10.03 (3.84)	10.81 (4.86)	0.276	0.603	NS
Biceps skinfold (mm)	5.33 (2.45)	5.53 (3.00)	0.045	0.834	NS
Chest skinfold (mm)	11.17 (6.18)	9.81 (5.43)	0.455	0.505	NS
Midaxillary skinfold (mm)	10.36 (5.40)	12.31 (7.42)	0.781	0.383	NS
Iliac crest skinfold (mm)	9.22 (5.14)	18.47 (10.37)	11.243	0.002	**
Abdominal skinfold (mm)	17.22 (10.18)	19.16 (10.96)	0.285	0.597	NS
Front thigh skinfold (mm)	12.67 (4.52)	16.37 (6.76)	3.611	0.066	NS
Medial calf skinfold (mm)	8.53 (3.84)	10.34 (4.73)	1.525	0.226	NS
Head girth (cm)	57.22 (1.60)	57.46 (1.76)	0.166	0.686	NS
Arm (relaxed) girth (cm)	32.97 (3.15)	32.42 (1.95)	0.388	0.538	NS
Arm (flexed and tensed) girth (cm)	34.99 (3.02)	34.60 (2.03)	0.197	0.660	NS
Forearm (maximum) girth (cm)	29.14 (1.88)	29.41 (1.23)	0.257	0.616	NS
Chest (mesosternale) girth (cm)	103.05 (7.57)	102.83 (5.94)	0.009	0.924	NS
Wais (minimum) girth (cm)	83.44 (7.61)	81.81 (6.27)	0.470	0.498	NS
Thigh (mid-troch-tib. lat.) girth (cm)	58.62 (4.69)	55.89 (3.59)	3.658	0.065	NS
Calf (maximum) girth (cm)	39.97 (3.00)	39.40 (2.29)	0.391	0.536	NS
Biacromial breath (cm)	42.33 (1.77)	42.34 (1.61)	0.000	0.990	NS
Transverse chest breath (cm)	30.81 (1.93)	30.72 (2.29)	0.017	0.897	NS
A–P chest depth breath (cm)	20.10 (3.01)	20.97 (1.80)	1.069	0.309	NS
Biiliocristal breath (cm)	29.28 (1.93)	28.52 (2.07)	1.214	0.279	NS
Humerus breath (cm)	7.01 (0.36)	7.13 (0.30)	1.145	0.293	NS
Femur breath (cm)	9.89 (0.65)	10.06 (0.55)	0.611	0.440	NS
Acromiale-dactylion length (cm)	83.24 (3.65)	82.97 (3.25)	0.053	0.820	NS
Acromiale-radiale length (cm)	34.99 (1.56)	35.74 (1.49)	2.100	0.157	NS
Radiale-stylion length (cm)	27.42 (1.84)	26.81 (1.41)	1.211	0.279	NS
Midstylion-dactylion length (cm)	20.83 (1.05)	20.42 (0.84)	1.643	0.209	NS
Radiale-dactylion length (cm)	48.25 (2.47)	47.22 (1.97)	1.816	0.187	NS
Endomorphy	2.78 (1.23)	4.06 (1.68)	6.575	0.015	*
Mesomorphy	5.16 (1.05)	5.34 (1.33)	0.185	0.670	NS
Ectomorphy	2.31 (0.99)	2.06 (1.20)	0.421	0.521	NS
Skin mass (kg)	4.31 (0.27)	4.23 (0.33)	0.556	0.461	NS
Muscle mass (kg)	41.36 (4.81)	41.35 (6.62)	0.000	0.994	NS
Adipose mass (kg)	21.39 (5.95)	23.71 (7.47)	1.017	0.321	NS
Bone mass (kg)	9.34 (1.18)	9.53 (1.29)	0.197	0.660	NS
Residual mass (kg)	9.67 (1.46)	9.53 (1.78)	0.066	0.799	NS

The mean difference is: not significant (NS).
* $P < 0.05$.
** $P < 0.01$.

Univariate ANOVA showed that there were significant differences between groups for 30-m sprint, sit-ups, handgrip strength (right and left) and back strength. Discriminant analysis showed that the standing vertical jump (coefficient = 0.876) was more discriminant than the variables 30-m sprint (coefficient = 0.789), sit-ups (coefficient = −0.774) or the right handgrip task (coefficient = 0.584). Moreover, the function ($\Lambda = 0.354$, $\chi^2(4) = 31.127$, $P < 0.001$) explain 88.2% of physiological variance (Table 2).

Team-handball-specific skills profile

The MANOVA indicated no significant differences between groups in technical skills evaluation ($\Lambda = 0.761$, $F_{7,26} = 1.164$). However, the ability to retrieve balls was significantly different when using the univariate ANOVA. Furthermore, the discriminant analysis ($\Lambda = 0.882$, $\chi^2(1) = 3.949$, $P < 0.05$) showed that the ability to retrieve balls (coefficient = 1.000) could discriminate between groups and explained 73.5% of the technical skills variance.

Table 2 Descriptive statistics of physiological characteristics for Successful and Less-Successful team-handball groups (mean (SD)), and independent samples comparisons.

	Successful	Less-Successful	*F*	*P-Value*	
30-m sprint time (s)	4.39 (0.20)	4.60 (0.32)			*
Speed-agility time (s)	22.66 (0.85)	23.05 (1.30)	1.090	0.304	NS
SJ (m)	0.34 (0.06)	0.37 (0.06)	2.557	0.120	NS
CMJ (m)	0.36 (0.06)	0.39 (0.06)	1.260	0.270	NS
ABK (m)	0.43 (0.06)	0.45 (0.07)	1.050	0.313	NS
DJ40 (m)	0.40 (0.07)	0.43 (0.09)	1.339	0.256	NS
SJA (m)	0.15 (0.05)	0.14 (0.06)	0.272	0.606	NS
CMJA (m)	0.21 (0.19)	0.13 (0.05)	2.535	0.121	NS
Sit-ups (#)	53.28 (10.22)	41.25 (8.27)	14.002	0.001	**
Handgrip right (kgf)	50.39 (8.25)	58.19 (8.94)	7.001	0.013	*
Handgrip left (kgf)	44.22 (8.81)	52.44 (10.56)	6.116	0.019	*
Back strength (kgf)	131.17 (20.90)	152.63 (32.72)	5.314	0.028	*
VO_{2max} (ml kg^{-1} min^{-1})	47.28 (3.36)	49.23 (5.43)	1.628	0.211	NS
Sit-and-reach (cm)	26.92 (6.55)	31.41 (8.42)	3.047	0.090	NS

SJ, Standing vertical jump; CMJ, countermovement vertical jump; ABK, Abalakov jump; DJ40, drop jump from 40-cm; SJA, standing vertical jump adapted to arms; CMJA, countermovement vertical jump adapted to arms.
The mean difference is: not significant (NS)
* $P < 0.05$.
** $P < 0.01$.

Considering tactical variables, the MANOVA showed that there was no difference between groups in what concerns the four game intelligence variables taken into account ($\Lambda = 0.923$, $F_{4,29} = 0.604$, $P > 0.05$), confirmed via ANOVA (Table 3).

Psychological profile

Performances in the three psychological tests (questionnaires) were similar between groups, and no significant differences were observed when using MANOVA ($\Lambda = 0.642$, $F_{8,25} = 1.742$, $P > 0.05$), in fact, the univariate ANOVA confirmed that the studied variables were not significantly different between groups (Table 4).

Multidisciplinary approach

Using all the previous significant and discriminant variables, a new stepwise discriminant function analysis showed that one function ($\Lambda = 0.200$, $\chi^2(6) = 46.603$, $P < 0.001$), with a combination of six variables, could successfully discriminate the groups studied (Successful = −1.827; Less-Successful = 2.055) and explained 94.1% of variance (cumulative). Moreover, the variables classification showed that the 30-m sprint time was the variable that best differentiated between groups followed by stature, the the ability to vary their actions, the performance on standing vertical jump, on handgrip (right) and on sit-ups (Table 5).

Table 3 Descriptive statistics of specific skills scores of Successful and Less-Successful team-handball groups (mean (SD)), and independent samples comparisons.

	Successful	Less-Successful	*F*	*P-Value*	
Defensive displacements	3.33 (1.33)	3.31 (0.79)	0.003	0.957	NS
Types of marking	2.39 (1.33)	3.06 (0.93)	2.846	0.101	NS
Ability to retrieve balls	2.33 (1.28)	3.13 (0.89)	4.274	0.047	*
Ability to escape the opponent	2.61 (1.33)	3.00 (0.97)	0.926	0.343	NS
Pass and reception	3.44 (0.98)	3.63 (0.62)	0.398	0.533	NS
Type of shots	3.00 (1.33)	3.25 (1.00)	0.376	0.544	NS
One vs one	2.50 (1.04)	3.13 (1.02)	3.091	0.088	NS
Ability to create and fill up spaces	2.67 (1.33)	3.13 (0.96)	1.302	0.262	NS
Offensive and defensive battle	2.78 (0.94)	3.19 (0.91)	1.652	0.208	NS
Defensive collaboration	2.67 (1.33)	3.13 (0.72)	1.508	0.228	NS
Ability to vary their actions	3.06 (0.87)	3.38 (0.50)	1.657	0.207	NS

The mean difference is: not significant (NS).
* $P < 0.05$.

Table 4 Descriptive statistics of psychological characteristics for Successful and Less-Successful team-handball groups (mean (SD)), and independent samples comparisons.

	Successful	Less-Successful	*F*	*P-Value*	
Task orientation	4.39 (0.49)	4.44 (0.35)	0.101	0.752	NS
Ego orientation	2.90 (0.59)	2.52 (0.72)	2.818	0.103	NS
Anxiety	14.06 (4.14)	13.56 (4.29)	0.116	0.735	NS
Social acceptance/rejection	20.17 (2.46)	19.06 (1.53)	2.405	0.131	NS
Self-efficacy	20.11 (1.49)	19.12 (1.86)	2.944	0.096	NS
Psychological maturity	15.61 (1.94)	15.81 (1.94)	0.091	0.765	NS
Impulsivity-activity	12.17 (1.50)	12.56 (1.71)	0.515	0.478	NS
Self-concept	73.72 (5.92)	71.88 (4.50)	1.028	0.318	NS

The mean difference is not significant (NS).

Discussion

The main purpose of the present study was to identify the variables that can distinguish between successful and less-successful team-handball athletes.

Our results showed that the successful team-handball athletes possessed a balanced mesomorph and the less-successful athletes had an endomorphic mesomorph somatotype. Moreover, significant differences between groups were observed as concerns the endomorphy category. This category successfully discriminated the two groups (explained 61.8% of variance). Also five anthropometric measures successfully discriminated between the two groups studied, namely: stature, chest skinfold, suprailiac skinfold, biiliocristal breath and radiale-dactylion length.

According to literature, body mass is determinant for performance, in the throwing events.[2] However, in this study, there is a small difference in body mass, between the groups, that can be confirmed by the small differences in muscle and bone mass although the successful group are significantly taller.

According to Ziv and Lidor,[5] team-handball is a dynamic team sport characterized by a high capacity to develop force level, great level of agility and flexibility. Nevertheless, significant differences between groups were observed in five physiological evaluations, i.e. the successful team-handball athletes recorded (i) higher values for sit-ups, (ii) faster times over the 30-m sprint, and (iii) lower values on dynamometry tests (handgrip and back strength) and in standing vertical jump. Was also observed that the averages of VO_{2max} were not different in the two performance groups, but unlike the results of Alexander and Boreskie[26] results (VO_{2max}: world champion, 53.1 ml kg^{-1} min^{-1}; non-world champion, 55.2 ml kg^{-1} min^{-1}), less-successful team-handball athletes had a superior VO_{2max} to successful ones. Furthermore, although Delamarche et al.[27] has reached the conclusion that the maximal aerobic power and capacity are prerequisites to the achievement of excellence in team-handball (age 18–21 years), and more recently Gorostiaga et al.[28] concluded that endurance capacity does not seem to be a limiting factor for elite performance in team-handball. In fact, our results suggest that team-handball players may not need to have an extraordinary aerobic capacity, but they must possess a reasonably high level aerobic capacity.

However, marked individual differences were observed among elite team-handball players in four physiological variables (that successfully discriminated between the two groups), namely: the standing vertical jump, the 30-m sprint, the sit ups and the right handgrip strength; which highlights the physical demands of the game. These results suggested that leg power is an essential component for success in athletic performance.[29,30] In other words, it seems that muscle mass and power are attributes to excellence in team-handball players.[28]

In general, morphologic and physiological attributes do have an important role on the all process of training evaluation, and physiological profiling can generate a useful database against which talented groups may be compared (explaining 88.2% of variance).

We are aware that the coach evaluation (team-handball-specific skills) is subjective and more or less dependent on the knowledge of the expert's assessment. Nevertheless, the ability to retrieve balls allows to discriminate successful and less-successful team-handball athletes (explain 73.5% of variance). Considering the game intelligence profile and psychological variables no significant difference was observed between groups. In fact, psychological profiles were similar. However, no research was found in literature that had compared the motivational orientation, anxiety and self-perception of professional male team-handball players of successful and less-successful handball teams.

Finally, multivariate statistical analysis techniques revealed that the two studied groups could be discriminated on the basis of six variables, and the most discriminating

Table 5 Stepwise discriminant analysis (standardized canonical discriminant function coefficients, eigenvalues and variance) for Successful and Less-Successful team-handball groups.

	Function
Stature	−0.631
30-m sprint time	1.122
Standing vertical jump	0.901
Sit ups	−0.720
Right handgrip	0.791
Ability to vary their actions	0.612
Eigenvalue	3.988
% of variance	100

was the performance on the 30-m sprint test (i.e. time), followed by the standing vertical jump (height), the right handgrip strength, the abdominal resistance (sit-ups), the stature and the technical ability to vary their actions. These results agree partially with the results observed (i) in elite female team-handball players[9]; and (ii) in young team-handball players.[3] In fact, it seems that in youth team-handball players, the skill test could be a good indicator to provide coaches with relevant information in the selection process. Nevertheless, we observed that (in adult male team-handball athletes) the determinants of success are multidisciplinary. In other words, our results suggested that the anthropometric (stature), physiological (standing vertical jump, right handgrip, sit ups) and cognitive and game intelligence (ability to vary their actions) profiles must be considered e training programs and in the selection process.

Conclusion

The battery test designed for this investigation was multidisciplinary in the sense that it embraced morphologic, physiological, handball-specific skills and psychological measures, which could be gathered in training conditions and did not require formal laboratory evaluations. The test battery proved to be of practical significance in so far as it successfully discriminated between groups of success and less-successful team-handball athletes. Moreover, performances on the 30-m sprint test, the standing vertical jump, the right handgrip strength, the sit-ups test, stature, and the ability of a player to vary their actions appear to be the strongest predictors of success in team-handball. Despite this multidisciplinary approach to success in team-handball is innovative, the small sample size weakens the study. In accordance, the next step would be (i) to examine the validity of discriminant variables (as predictors) in a large sample of adult team-handball players, (ii) to establish whether the new protocol proves useful in discriminating between successful handball players, and (iii) to establish baseline reference data for the development of perceptual training programs and talent identification of potential elite male team-handball players.

Conflict of interest

The authors declare that they have no competing interests.

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