

Anthropometric profile of the top-class female handball players participating in the Olympic Games Tokyo 2020

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Abstract

Study aim: The aim of this study was to try to determine the factors that differentiate the height, weight, BMI, and age of high-level female handball players participating in the Tokyo 2020 Olympic Games.

Material and methods: The recorded study material was analyzed in the context of the position in the game, RAE, the continental location of the represented country, and geographical region. Statistical tests were used: Student's t-test, ANOVA using the b-Tuckey post-hoc test, the Mann-Whitney U test, and the Kruskal-Wallis test.

Results: The results show that the position of the game differentiates the height and body mass, and the effect size is large. Differences occur for all positions in the game. Interactions were shown within the body weight, BMI, and age of the athletes. The highest average heights, weights, and BMIs are found in female players playing in the pivot, while the lowest are found in right wing.

Conclusion: The factors that most strongly differentiate the height and weight of female players are the nominal position in the handball game. Center backcourt players are characterized by lower height and weight values than left back players, so it is necessary to determine average values separately for the mentioned positions in future analyses. The results indicate the presence of numerous interactions involving RAE, which indicates a substantive need for studies at other levels of play to confirm their occurrence.

Key words: Height – Weight – BMI – Position – Relative age effect

Introduction

The literature points to papers focusing on height, weight, and BMI measurements in junior soccer [1, 7], basketball [33, 44], volleyball [28, 44], judo, swimming, and table tennis [44]. Works with this theme also apply to senior soccer [41], futsal [40] volleyball [4], and rugby [30, 38].

Previous studies point to various factors that differentiate athletes' body height, body weight, and BMI. It should be pointed out that there are differences in these parameters depending on the sport played [44]. The position of the game differentiates the body height, and body weight of soccer [41] and rugby players [30, 38]. Among futsal players, higher body height was indicated in players staying on the court [40]. In volleyball, body height, body weight, and BMI vary according to playing position as well as final ranking in games [28]. Previous studies

also indicate that the level of play is a differentiating factor between height and weight in rugby [38] and volleyball [4, 28]. It should be pointed out that in some reports, talent identification in soccer and basketball includes the height and body weight of players [27]. The literature also indicates that height and weight vary according to RAE (relative age effect) in adolescents training in soccer [1, 7] and basketball [33].

The issues of height, weight, and BMI in handball players are the subject of numerous scientific reports. Longitudinal studies indicate that the height, body weight, and BMI of players at top-level events are steadily increasing (2004-2021) [15] and that players exhibit higher body heights relative to the general population [3].

In addition to longitudinal studies indicating differences over many years among handball players, it is also important to point to reports indicating factors that differentiate parameters such as height, weight, and BMI. Previous studies indicate that men have higher values for height

and weight relative to women, in the group of players with a high sports level [19, 36]. The results also indicate that the age category of players is a factor that differentiates anthropometric parameters, which are higher in older players. These differences are found in both men [2, 10, 36, 43] and woman [2, 36, 37].

The literature also contains works that focus on the study of relationships relating to height, weight, and BMI in the context of handball game analysis. One of the factors differentiating the above parameters is the level of play at which the players perform. In the group of seniors, higher body height indices were registered in players with a higher sports level [9], and this also applies to body weight and BMI [16]. Referring to female handball players, it should be pointed out that players at the highest sports level are characterized by higher height and weight indices and no differences in BMI in relation to those playing at lower levels of competition [8, 22].

In terms of correlation, it is important to point out the positive relationship between body height and throwing speed (in various throwing techniques) among juniors [43] and seniors [9, 39]. Among female handball players at the junior and senior levels, a positive correlation was also found between body height and throwing speed [37]. The results also show a correlation between body weight and throwing speed [43] and jump high [10] in the junior women's group. In the women's group of both juniors and seniors, there is a correlation between body weight and squat jump, medicine ball throw, and throwing speed from 7 and 9 meters [37]. Correlational studies have shown an association between BMI and throwing speed in a group of men playing at the junior and senior level, and indicate that BMI is one of the predictors of the speed given to the ball during the throw [43]. Among female juniors and seniors, BMI only correlates with performance in the medicine ball throw [37]. Research indicates that among elite female soccer players, there are non-linear relationships between body height and BMI and change of direction speed [CODS] and agility [AG] (peak of CODS for body height – 183 cm and for BMI – 25.45; peak of AG for body height – 182.23 cm and for BMI – 26.27) [29].

An analysis of the literature indicates that handball playing position is a factor that differentiates players' height, weight, and BMI. Longitudinal studies of championship events have shown that average values have been steadily increasing over the past 18 years for all positions (except the height and weight of goalkeepers) [15]. The results of previous studies indicate the highest height and weight parameters for players playing on pivot positions in a group of handball players at the senior level [9, 21]. The results also indicate the lowest average height and weight values in players playing on the wing positions at both junior and senior levels [26]. The results of previous

studies indicating significant differences between players in different positions: height, weight and BMI: P (pivot), backcourt > wing; body height: P (pivot) > wing; GK (goalkeeper) weight, P (pivot) > wing, which apply to both men playing at junior and senior level [2, 17]. Referring to female handball players, it is important to point out the occurrence of similar trends as in men. Body height and weight are higher in P (pivot) and backcourt players in relation to wing players, while BMI is higher in P (pivot) than in backcourt and wing players at both junior and senior levels [2, 26]. Previous reports also indicate that there are differences in the described parameters between players in different positions in the context of the level of play. In the group of men at the higher level of play, the highest body height was registered for P (pivot), while at the lower level the highest measurement results occurred in backcourt players [9]. Similar trends were registered among female handball players. At the higher level of play, wing players are characterized by lower height and body weight in relation to pivot and backcourt positions. At a lower level of play, female wing players are characterized by lower height and weight in relation to backcourt players and goalkeeper, and pivot positions have higher height and weight than female handball players playing on wing and goalkeeper positions [20].

Referring to the height and weight and BMI of male and female handball players, it should be pointed out that in the junior group, the quarter and term of birth is not a factor that differentiates them [42], which is the case in other team games [1, 7, 33].

The presented literature review provides a substantive rationale for addressing the subject of body height, body mass, BMI, and age of handball players at the level played by many sports theorists and practitioners for the highest, i.e. the Olympic Games. This is to see the latest trends in handball relating to the described variables. The presented research results also indicate the need to search for and describe factors differentiating the height and weight, BMI, and age of female handball players at a high sport level.

The aim of this study was to try to determine the factors that differentiate the height, weight, BMI, and age of high-level female handball players participating in the Tokyo 2020 Olympic Games.

Materials and methods

Participants

The study group consisted of female handball players with a high level of sportsmanship ($n = 179$), who were participants at the Tokyo 2020 Olympic Games. The average age of the players was 28.18 ± 4.47 years, body height 175.17 ± 6.62 cm, body mass 70.40 ± 8.79 kg and BMI 22.90 ± 2.07 .

Procedures

The study material was obtained from the official website of the International Handball Federation IHF (www.ihf.info). The dependent variables were data on body height [cm], body weight [kg], and age [years]. BMI was calculated according to the formula:

$$\text{BMI} = \frac{\text{body mass [kg]}}{\text{body height [m]}^2}.$$

The recorded study material was analyzed in the context of the position in the game: left wing [LW] (n = 22), left back [LB] (n = 30), center back [CB] (n = 30), right back [RB] (n = 24), right wing [RW] (n = 20), pivot [P] (n = 27) and goalkeeper [GK] (n = 26). To examine the differences between the studied variables with RAE (relative age effect), the athletes were divided into four groups based on their date of birth (Q1: January 1 – March 31 (n = 43), Q2: April 1 – June 30 (n = 45), Q3: July 1 – September 30 (n = 45), Q4: October 1 – December 31 (n = 46)). In the following analysis, female handball players were divided into two semesters based on their date of birth (S1: January 1 – June 30 (n = 88), S2: July 1 – December 31 (n = 91)). The collected study material was also analyzed in the context of the continental location of the represented country: Africa [AF] (n = 14), Asia [AS] (n = 30), Europe [E] (n = 120), South America [SA] (n = 15) and geographical region: Europe [E] (n = 120), Others [O] (n = 59).

Statistical analysis

The collected study material was subjected to statistical analysis. The normality of distribution was tested with the Shapiro-Wilk test. The homogeneity of variance was tested with Levene's test. Parametric tests were used for normal distributions. Differences between two independent groups were tested with Student's t-test. Differences between more than two independent groups were tested by ANOVA using the *b*-Tuckey post-hoc test. For distributions that did not meet normality assumptions, non-parametric tests were used: the Mann-Whitney U test for two independent groups and the Kruskal-Wallis test for more than two independent groups. The partial eta-square (η^2) was used to determine the effect size [ES] (<0.01 – no effect, 0.01–0.059 – small effect, 0.06–0.139 – intermediate effect, >0.14 – large effect) [5]. All statistical analyses were performed using TIBCO Statistica 13.3 and Microsoft Office Excel software.

Results

The results of statistical analyses of the factors that differentiate the variables studied are presented in Table 1.

The results presented show that the position of the game differentiates the body height of the players, and the effect size is large. It is shown that P players and GK are characterized by higher body height in relation to CB, RW, RB, and LW. LB players manifest a higher body height than CB, RW, and LW. In addition, it should be noted that the highest body height was registered among female players in the P, LB, and GK positions, while the lowest was for RW and LW.

The analysis proves that one of the factors differentiating body height is the geographical location of the country represented (continent). Female players from E manifest a higher body height than female handball players from AS, and the effect size is intermediate.

The difference in the body heights of female players in the context of the world region was shown. Handball players from E have a higher body height than players from other continents, however, the effect size is small.

The results of the study indicate that the differentiating factor of body weight is the position in the game, and the effect size of these analyses is large. It was shown that female players playing in the P position have a higher body weight than female players playing in the CB, RW, RB, and LW positions. Higher body weight was registered for GK and LB in relation to CB, RW, and LW. The results of statistical analyses also indicate that the body weight of RB is higher than that of RW. It should additionally be stated that the highest body weight is characterized by P and GK athletes, while the lowest is for RW and LW.

Analysis of the data showed that handball players from the AF continent have a higher body weight than AS, and the effect size is small. It should be noted that female players from Europe showed the least variation in body weight (SD = 6.78), while players from other continents showed higher variation in the described variable (SD > 10).

The results of statistical analyses on BMI indicate that there is a difference between P and RW players in terms of playing position, and the effect size is small.

Differences were shown within BMI according to continental location, and the effect size of these differences is intermediate. Female athletes from AF have a higher BMI than female handball players from E and AS.

It has been shown that female players from E have a lower BMI than female handball players from other continents, and the effect size is intermediate.

The results presented show that none of the independent variables differentiate the age of the athletes.

The results of statistical analyses of interactions between the variables studied are presented in Table 2. Due to a large number of variables, only statistically significant results are presented. Interactions were shown within the body weight, BMI, and age of the athletes.

Table 1. Factors differentiating height, weight, BMI and age of female handball players

Variables	Body height [cm]	Body weight [kg]	BMI (kg/height [m]) ²	Age [years]
	M ± SD	M ± SD	M ± SD	M ± SD
Position				
LW	170.05 ± 3.93	63.68 ± 4.21	22.02 ± 1.23	28.77 ± 3.57
LB	179.57 ± 5.47	73.13 ± 6.07	22.68 ± 1.59	28.53 ± 4.17
CB	172.10 ± 5.81	67.23 ± 5.94	22.70 ± 1.66	27.63 ± 3.85
RB	173.42 ± 5.44	68.75 ± 6.16	22.82 ± 1.20	26.88 ± 4.51
RW	169.10 ± 5.01	62.60 ± 4.25	21.91 ± 1.45	28.90 ± 4.83
P	180.11 ± 5.12	78.04 ± 10.11	24.02 ± 2.56	27.00 ± 4.16
GK	179.12 ± 4.31	76.15 ± 9.33	23.76 ± 3.10	29.81 ± 5.69
Test	ANOVA F(6,172) = 21.231, p = 0.00, η^2 = 0.425	KW-H(6,179) = 76.513, p = 0.00, η^2 = 0.41	KW-H(6,179) = 15.277, p = 0.018, η^2 = 0.054	KW-H(6,179) = 8.044, p = 0.235, η^2 = 0.012
Differences	P>CB***, RW***, RB***, LW***, GK>CB***, RW***, RB***, LW***, LB>CB***, RW***, LW***	P>CB***, RW***, RB*, LW***, GK>CB*, RW***, LW***, LB>CB*, RW***, LW***, RB>RW*	P>RW*	
Birth quarter				
Q1	174.23 ± 6.03	69.58 ± 8.06	22.90 ± 2.14	27.81 ± 5.03
Q2	175.64 ± 6.54	72.44 ± 10.57	23.42 ± 2.63	29.11 ± 3.78
Q3	176.20 ± 7.62	70.73 ± 9.13	22.72 ± 1.82	28.18 ± 4.12
Q4	174.57 ± 6.17	68.83 ± 6.82	22.56 ± 1.50	27.63 ± 4.84
Test	ANOVA F(3,175) = 0.854, p = 0.466, η^2 = 0.014	KW-H(3,179) = 3.367, p = 0.338, η^2 = 0.002	KW-H(3,179) = 2.898, p = 0.407, η^2 = 0.048	KW-H(3,179) = 4.039, p = 0.257, η^2 = 0.006
Birth semester				
S1	174.95 ± 6.30	71.05 ± 9.49	23.16 ± 2.40	28.48 ± 4.46
S2	175.37 ± 6.94	69.77 ± 8.06	22.63 ± 1.66	27.90 ± 4.48
Test	T-Test t(1,177) = -0.423, p = 0.673, η^2 = 0.001	U M-W Z = 0.716, p = 0.474, η^2 = 0.003	U M-W Z = 1.085, p = 0.278, η^2 = 0.007	U M-W Z = 0.681, p = 0.496, η^2 = 0.003
Continent				
Africa [AF]	174.79 ± 6.68	78.21 ± 12.39	25.50 ± 3.01	27.43 ± 5.00
Asia [AS]	171.40 ± 7.06	68.13 ± 10.32	23.12 ± 2.45	28.70 ± 3.95
Europe [E]	176.15 ± 6.21	69.64 ± 6.78	22.41 ± 1.40	27.95 ± 4.41
South America [SA]	175.20 ± 6.64	73.67 ± 11.82	23.88 ± 2.65	29.73 ± 5.38
Test	ANOVA F(3,175) = 4.376, p = 0.005, η^2 = 0.070	KW – H(3,179) = 10.197, p = 0.017, η^2 = 0.041	KW – H(3,179) = 20.105, p = 0.0002, η^2 = 0.098	KW-H(3,179) = 2.538, p = 0.468, η^2 = 0.003
Differences	E>AS*	AF>AS*	AF>E***, AS*	
Region				
Europe [E]	176.15 ± 6.21	69.64 ± 6.78	22.41 ± 1.40	27.95 ± 4.41
Others [O]	173.17 ± 7.02	71.93 ± 11.80	23.88 ± 2.77	28.66 ± 4.59
Test	T-Test t(1,177) = 2.891, p = 0.004, η^2 = 0.05	U M-W Z = -0.362, p = 0.717, η^2 = 0.005	U M-W Z = -3.500, p = 0.0005, η^2 = 0.068	U M-W Z = -1.095, p = 0.273, η^2 = 0.007
Differences	E>O		O>E	

LW = left wing; LB = left back; CB = center back; RB = right back; RW = right wing; P = pivot; GK = goalkeeper; Q1-Q4 = birth quarter; S1-S2 = birth; KW = Kruskal-Wallis test; U M-W = Mann-Whitney U test; semester; p = level of significance; η^2 = effect size; * = p<0.05; ** = p<0.01; *** = p<0.001.

Statistical analyses identified three significant interactions for female athletes' body weight.

It was shown that the body weight of P female athletes born in Q2 is higher than those born in Q1 and Q4, and the effect size is large.

The body weight of female athletes born in Q2 is higher in O than in E, and the effect size is large. Among female athletes from the O region, those born in Q2 have a higher body weight than those born in Q3. The effect size of these differences is intermediate. Statistical analyses indicate that among female handball players from the O region, higher body weight is found among those born in S1 relative to S2, and the effect size is intermediate.

The data in Table 2 show that five statistically significant interactions were demonstrated for the BMI variable.

The results presented indicate that female handball players playing in the P position born in Q2 have a higher BMI than those born in Q1 and Q4, and the effect size is large.

It has been shown that female players playing in the LB position with E have a lower BMI in relation to female handball players from other continents, and the effect size is large. It should be pointed out that handball players born in Q1 and Q2 in E have a lower BMI than players from the

other O continents, and the effect size of these analyses is large.

The BMI in the group of female handball players from region O born in S1 is higher in relation to S2, and the effect size is intermediate. In the group of female representatives born in S1, a lower BMI was registered for female handball players from E than from region O, and the effect size obtained is large.

When considering the differences in BMI for female handball players born in S1, it should be pointed out that players from E are characterized by a lower level than players from AF and SA, and the effect size is large.

The results presented show two significant interactions within the age of female handball players. It was shown that the age of female handball players playing in the RB position in E is lower than for players from other continents, and the effect size is large.

In the group of female athletes with SA, those born in S2 appeared to be older than S1, and the effect size of these analyses is large.

Analysis in relation to the term of birth showed that players born in S2 in SA are older than handball players from E, and the effect size is intermediate.

Table 2. Interactions between body weight, BMI and age of female handball players for independent variables

Variables	Interactions	Differences	Result
Body weight	Birth quarter*position	P: Q2 (86.86 ± 10.65) > Q1 (68.75 ± 5.97)*, Q4 (72.00 ± 4.53)*	KW-H(3,27) = 15.127, $p = 0.002$, $\eta^2 = 0.527$
	Birth quarter*region	Q2: E (69.48 ± 7.31) < O (80.58 ± 13.87)	U M-W Z = -2.862, $p = 0.004$, $\eta^2 = 0.184$
		O: Q2 (80.58 ± 13.87) > Q3 (68.64 ± 13.49)*	KW-H(3,59) = 8.226, $p = 0.041$, $\eta^2 = 0.096$
	Birth semester*region	O: S1 (74.58 ± 12.38) > S2 (69.00 ± 10.57)	U M-W Z = 1.966, $p = 0.049$, $\eta^2 = 0.066$
BMI	Birth quarter*position	P: Q2 (26.32 ± 2.41) > Q1 (22.26 ± 1.80)*, Q4 (22.48 ± 1.84)*	KW-H(3,27) = 13.554, $p = 0.004$, $\eta^2 = 0.459$
	Region*position	LB: E (22.07 ± 1.27) < O (24.09 ± 1.42)	U M-W Z = -3.009, $p = 0.003$, $\eta^2 = 0.306$
	Birth quarter*region	Q1: E (22.13 ± 1.36) < O (23.87 ± 2.55)	U M-W Z = -2.47, $p = 0.013$, $\eta^2 = 0.143$
		Q2: E (22.51 ± 1.56) < O (25.91 ± 3.37)	U M-W Z = -3.657, $p = 0.0002$, $\eta^2 = 0.299$
	Birth semester*region	O: S1 (24.66 ± 3.01) > S2 (23.01 ± 2.21)	U M-W Z = 1.966, $p = 0.049$, $\eta^2 = 0.066$
		S1: E (22.35 ± 1.47) < O (24.66 ± 3.01)	U M-W Z = -4.101, $p = 0.00004$, $\eta^2 = 0.192$
	Birth semester*continent	S1: E (22.35 ± 1.47) < AF (26.39 ± 3.34)*, SA (25.57 ± 3.30)*	KW-H(4,88) = 21.9, $p = 0.0001$, $\eta^2 = 0.225$
Age	Position*region	RB: E (25.37 ± 3.72) < O (29.88 ± 4.67)	U M-W Z = -2.143, $p = 0.032$, $\eta^2 = 0.197$
	Birth semester*continent	SA: S1 (26.17 ± 5.08) < S2 (32.11 ± 4.31)	U M-W Z = -1.96, $p = 0.05$, $\eta^2 = 0.268$
		S2: SA (32.11 ± 4.31) > E (27.40 ± 4.31)*	KW-H(3,91) = 9.296, $p = 0.026$, $\eta^2 = 0.072$

LW = left wing; LB = left back; CB = center back; RB = right back; RW = right wing; P = pivot; GK = goalkeeper; Q1-Q4 = birth quarter; S1-S2 = birth; KW = Kruskal-Wallis test; U M-W = Mann-Whitney U test; semester; p = level of significance; η^2 = effect size; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Discussion

Statistical analyses of the collected study material showed that the differentiating factors of body height are the position in the game, the geographical location of the country represented, and the region of the world. The average body height results of the female athletes correspond with reports by other authors [2, 20].

Referring to the position in the game also, it should be said that the presented research results coincide with those presented by Michalsik et al. [20]. However, it should be noted that in the cited article, the authors did not distinguish the exact position in the game, and the division included only wing, backcourt, and pivot players, and for players with a high level of sportsmanship, goalkeepers were not included. The peculiar inadequacy of this approach is indicated by the results presented in this paper, which show differences within female backcourt (CB < LB). It should also be pointed out that P and GK are significantly higher than CB, RW, LW, and importantly RB. The present results indicate that future research should take into account the exact position in the game, as this can indicate both emerging trends and the determination of accurate results within a specific position in the game. Such an approach can serve as a benchmark for recruitment and selection in handball, as well as for talent identification at the sports training level in youth groups, as in other sports [27]. When comparing the general trends shown in body height in the context of playing position, they correspond with the results of other authors indicating that P and backcourt players are characterized by significantly higher parameters in relation to wing players [2, 20]. Similar trends are also found among men of the highest sporting level [2, 17, 21]. Such differences are due to technical-tactical actions specific to players playing a particular position during a handball match, which should be taken into account to some extent in the recruitment and selection process. It is necessary to point out the correlation between the height of the body and the speed given to the ball during the throwing [37], which, when playing in the backcourt position, is a dominant ability derived from the game. Also, playing in the P position predestines players characterized by a higher body height to gain an advantage of physical conditions over defenders. A similar situation occurs in defensive play, affecting the ability to block opponents' throws and forcing them to look for more difficult solutions mainly in positional attack, which can result in increased efficiency of defensive play. In the case of the game on goal, the higher body height and thus a greater range of defense allows the player to cover a larger area of the goal light with her own posture, which consequently limits the throwing capabilities of the attacking players while forcing them to make more technically advanced throws, resulting in more effective interventions.

The reason for the demonstrated differences in body height across continents and regions of the world represented by female athletes should be attributed to genetic inter-population differences. Previous population studies indicate that women from Europe have the highest body heights. Such trends have been observed for both female minors [32] and adults [12, 23]. The differences shown may also be due to the popularity of handball on each continent, which may translate into a larger number of youngsters participating in the training process, resulting in the possibility of selecting players with appropriate growth parameters at all stages of training. Such an approach, however, requires additional research relating to the number of young players and control of growth rates at different stages of training depending on the continent and geographic region of the world.

The results presented indicate that playing position is a differentiating factor in the body weight of the players included in the study. It should be noted that the highest results are characterized by handball players playing in P and GK positions, while the lowest results are those playing in the wing position. The results obtained correspond with the results of other authors referring to both the average values and the differences between the positions of the game in the group of athletes of high sport level [2, 20]. As a factor in such differences, it is important to point out body height, which correlates strongly with body weight, and within which similar results have been shown [37]. Similar trends have been shown among male handball players with a high level of sportsmanship [2, 17, 21], which indicates the specificity of the game at particular handball positions. It should also be pointed out that in the group of female handball players, there is a correlation between body mass and the height of the squat jump and the speed given to the ball during the throw from 9 meters, which is the domain of players playing in the backcourt position. A characteristic action of players playing in the P position is the proper execution of the cover-up, in which body weight undoubtedly plays a role, since defensive players with a very contact game have a difficult task of effective defense. It should be pointed out that the game of wing positions requires adequate dynamics, which, in a situation of excessive body mass, can affect its reduction and, as a result, cause a decrease in the effectiveness of sports combat. The results presented also indicate differences between LB and CB, which indicates that these positions should be treated separately in future studies. The literature also indicates that body mass and BMI, which correlate with each other, are predictors of the quality of handball play in the women's group [37].

When discussing the differences in body weight between female athletes from AF and AS in the absence of differences in body height, the results obtained should be considered holistically. Learning about the observed

differences requires further anthropometric studies of teams from AF and AS taking into account the population within the continent from which the athletes come, with particular attention to fat mass measurements. For an in-depth analysis, attention should also be paid to the training process within the intensity and emphasis on shaping strength, as in a group of handball players subjected to strength training over an 8-week cycle, body mass in the experimental group decreased [11], which may also be the case in the group of female athletes studied.

The BMI results obtained in relation to playing position indicate that differences exist between P and RW players. Such a condition may be due to the fact that height and weight are the highest for P players, while the lowest for RW. In modern handball for playing on the right side of the court (RB, RW) there is a preference for players for whom the left hand is dominant. This approach facilitates the execution of technical elements, in particular the throw to the goal, as there is a greater throwing angle, so that players have opportunities to make a throw into the intended sector of the goal. Previous studies indicate that the percentage of left-handers in the general population is about 10% [6, 13], which may indicate that left-handedness is a factor more often taken into account in the recruitment and selection process than height, weight, and BMI. The results obtained are partially consistent with data presented by other authors, who indicate that female P athletes registered a significantly higher BMI than backcourt and wing possessions. Such differences indicate the need for further scientific investigation to study and describe the present phenomenon as widely as possible and to follow the latest trends resulting from the development of handball.

Discussing the differences in BMI by continent, it should be pointed out that female athletes with AF are characterized by its higher level in relation to E and AS. Such a condition may be due to general trends in BMI levels in the global population, where it is highest for the population with AF [24, 25]. To gain a closer understanding of the demonstrated differences, further studies should be conducted that take into account analysis of the training process, body composition with a particular focus on fat mass, and lifestyle and nutrition studies that can bring closer insight into the demonstrated differences. The same conclusions apply to the demonstrated differences between female athletes from E and O in the context of the world region.

The results presented indicate that there is an interaction between the variables included in this study. An interaction is shown for the P position for body mass and BMI in the context of the birth quarter. Given the relationship between body mass and BMI, the results are the same with each other, with the highest occurring in the group of handball players born in Q2. There may be many reasons for this, which requires further research into the present

problem. Previous studies indicate that in youth groups in team games, RAE is a factor that differentiates body weight and the level of motor skills [1, 7] as well as being a determinant of the start of a senior career [18]. Therefore, it can be presumed that players born in the first quarters of the year enter puberty earlier, which translates into a jump in weight gain and BMI, which in the context of the requirements of playing in the P position is one of the main features. Such a mechanism may lead to early specialization of the game in a specific position, as indicated by the observed results. Within the BMI for LB, it was shown that a lower level occurs for players with E in relation to the others. Such a condition may be indicated by the results of population studies showing lower levels for women from E in relation to the other continents [24, 25]. To expand our knowledge and accurately describe the differences shown, further research should be conducted on the analysis of the training process within the content and intensity of exercise, as well as body composition studies.

Discussing the results obtained regarding body weight and BMI, which are correlated in female handball players [37], it is necessary to point out the tendency that higher values occur in players from the O region in relation to E born in the first quarter and first semester of the year. In an attempt to determine the reasons for the observed state of affairs, it is also important to point out the differences in BMI occurring between E and O [24, 25]. The resulting differences may also occur due to the popularity of the discipline, and thus the timing of when girls begin training. Starting training at an early stage of development in pre-adolescence allows for the acquisition of technical and tactical skills. Starting training at puberty will promote female athletes whom it occurs earlier due to weight gain, and thus BMI, due to greater possibilities in the level of motor skills, which even with a lower level of technical and tactical training will give an advantage during the game. Previous research can support such a conclusion, as RAE has been observed in relation to athletic performance in basketball [33], soccer [31] and handball [34, 35]. Findings also indicate a correlation between RAE and the quality of play in handball [14, 34].

The results indicate that players playing in the position of RB from E are younger than those from other continents. In order to explain the differences, further longitudinal studies should be conducted, focusing on the analysis of the careers of individual players. It can be speculated, however, that one of the indirect reasons for this is the popularity of the discipline, which may translate into a greater number of players in the youth stages of training. This may affect the greater possibility of selection in the training process and, consequently, achieving a higher level of sportsmanship, which gives the opportunity to play in national teams earlier. It should also be taken into account that in modern handball the RB position is played

mainly by left-handed players, whose percentage in the population is lower [6, 13]. Such a condition may affect the longer continuation of the careers of players from outside the E. It can also be conjectured that players from the E play a very large number of matches per year at a high sporting level (national teams, clubs), which affects high training loads, and injuries, which may cause the earlier ending of sports careers. It can be assumed that such a picture also consists of several sociological reasons, which may include social status, education, and having offspring during the career, however, this requires further thorough research focusing on the analysis of the careers of female athletes with a high sporting level. The arguments raised above can also provide a basis for explaining the differences in the age of female athletes from S2, where a higher average is found among female representatives from SA than from E. The results obtained indicate a higher average age of female athletes from SA born in S2, and the difference is significant. However, due to the small study group, further research should be conducted on a larger number of female athletes from SA with a high level of sportsmanship in order to show whether this occurs in the entire population of female athletes.

Limitations

The athletes subjected to the research process are characterized by their high level of sportsmanship. The obtained results bring a number of new and cognitively valuable information regarding the research topic, however, the limitations of the present study are the small number of female athletes included in the study from continents other than Europe, which is due to the organization of the Olympic Games tournament. In order to verify and generalize the results obtained, further research should be carried out in the scheme adopted in this study on a larger number of female athletes from each continent with a high level of sportsmanship.

Conclusion

The factors that most strongly differentiate the height and weight of female players are the nominal position in the handball game. The highest average heights, weights, and BMIs are found in female players playing in the pivot position, while the lowest are found in right wing players. Center backcourt players are characterized by lower height and weight values than left back players, so it is necessary to determine average values separately for the mentioned positions in future analyses. The factor that differentiates height, weight, and BMI is the continent from which the players come. The strongest interactions for body mass and BMI are found for pivot players depending on the quarter of

birth. The results indicate the presence of numerous interactions involving RAE, which indicates a substantive need for studies at other levels of play (senior and youth) to confirm their occurrence. The differences shown also indicate the need for further scientific investigation relating to the registration of anthropometric traits at events of different rank in order to follow the latest trends in this area.

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