Article

Does Age, Experience and Body Fat Have an Influence on the Performance of Handball Referees?

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Abstract: The purpose of the study was to determine the correlation of quality of the refereeing in handball with the morphological characteristics of referees, along with their age and experience. Subjects are 16 pairs (N = 32) of top-level handball referees in Croatia (age 34.66 ± 6.44, height 184.02 ± 5.87 cm, body mass 91.14 ± 10.61 kg, body fat 19.20 ± 3.94% and body mass index 26.91 ± 2.47 kg/m^2) which have conducted morphological measures and tests for determination of their morphological status in the first part of the study. In the second part of the study, referees were evaluated in top-level handball matches to determine if their morphological status had an influence on the quality of refereeing. The correlation of quality of the refereeing with body fat was tested and there is no significant correlation ($p = 0.75$). Pearson's correlation coefficient proves that total experience in refereeing does not have an influence on the quality of refereeing (r = 0.30), and neither does the age of referees (r = 0.23). Experience of refereeing in the highest rank has a statistically significant influence on the quality of refereeing (r = 0.62). Existing elimination criteria (measurement of morphological characteristics and functional abilities at official tests) that referees must satisfy at official seminars before the beginning and in the middle of the season make the selection of referees. Based on these facts, it is concluded that the existing selection of referees is good and there is no great variability among them, considering their morphological characteristics. Experience in refereeing is significant for the quality of refereeing, especially experience in the highest level of competition.

Keywords: morphological characteristics; body composition; physical condition; quality of refereeing; anthropometry

1. Introduction

Handball is a dynamic sports game and players, as well as two equally important referees who officiate handball matches, must be coordinated and extremely cooperative amongst themselves. Referees need to make equal conditions for all players so they can play and adhere to the pre-established written rules of the game. In the literature, there is an overview of scientific knowledge of handball referees where, according to the complexity of handball as a sport, technical complexity, and high speed of handball games, it is considered that handball is a very tough and very stressful sport for refereeing. The success of refereeing is closely linked to the ability to monitor physical and physiological demands during the game [1,2]. For this reason, handball referees must be conditionally and mentally prepared to a level that allows them to properly follow those aspects of the game. In several scientific studies [3–5], a negative correlation was found for higher body fat levels with the level of motor or functional abilities such as speed, explosive power (the ability to overcome resistance with a high contraction rate [6]), coordination, agility (rapid whole-body movement with a change in velocity or direction in response to a stimulus [7]) and aerobic (low-intensity exercise activity) and anaerobic capabilities (anaerobic power is power used in high-intensity exercise activities lasting fewer than ten seconds which is the peak amount of time for phosphocreatine reserves to empty as a primary fuel source [8]).

In the recent past, success in handball was mostly based on the technical preparedness of players, unlike today when modern handball requires players to have a higher level

of physical fitness [9,10] along with a high technical background. Physical preparation of referees must be at a level that avoids fatigue and physical exhaustion during matches which prevent proper decision-making [11], and correct decisions come with accurate positioning [12]. Distance from the place of action is very important in making the right decision which depends on several factors such as place on the court, match time and physical condition of the referees [2,13,14]. As the physical loads of referees are very high during matches and they are correlated with the rank of competition [15,16], referees need to increase their indicators of maximum abilities to be able to cope with all the requirements of handball matches which are dictated by players [17]. With athletic appearance referee gain authority which is extremely important for refereeing and managing control of the match, and consequently making the most difficult decisions more easily with levied authority. In modern handball, the basic rules of the game have changed. These changes have affected the speed, the number of attacks, the transformation in the game, and the overall pace of the game. As a direct consequence of changing the rules of the game, the preparatory period of the attack is reduced which has led to more dynamic and faster games and more sophisticated tactics in the game [18]. In accordance with the rule which allows a fast restart of the game after the goal was scored by the attacking team, it contributed to the higher physical requirements of the players [19], as well as referees [20] whose physiological loads during the game may be higher than the physiological loads of the player during the match [11]. Handball referees have multiple tasks during a match which are much easier to perform if they are physically prepared and do not need to concentrate on their physical disadvantages but can concentrate on more important and relevant events during the match.

Handball referees must cope with mental pressure [21] in the form of stress as the work of sports referees is recognized as a very stressful activity. Stress leads to insomnia, inappropriate diet, metabolic problems, diseases, and other factors which lead to a higher percentage of subcutaneous fat tissue, and consequently higher body mass. Experience in refereeing, along with the number of hours spent in theoretical and practical training and the number of officiated games is extremely important and positively correlated with skill of refereeing [13]. Significant parameters in the selection of handball players are anthropometric characteristics (knowledge of dominant characteristics for selection in handball), organs and organic systems functional abilities (aerobic and anaerobic capacity), motor skills, social characteristics, and cognitive and conative characteristics [22]. Morphological characteristics are an integral part of elimination criteria for referees at official seminars before and in the middle of the season. This applies primarily to the body mass and in some handball federations, it applies to the percentage of subcutaneous fat tissue or the body mass index.

The aim of this research is to establish the correlation between the quality of the refereeing in handball with the morphological characteristics of handball referees, their age and experience in handball matches. The purpose of the research is to determine which variables that are included in this research make difference between the referees in quality at the end of the season. Based on these assumptions, the hypothesis says there is a statistically significant negative correlation between a higher percentage of body fat and a lower quality of refereeing. Additionally, the correlation of age, career length and experience with the quality of refereeing will be tested to check if any of those have an influence on the performance of the referee, i.e., the quality of the individual referee itself.

2. Materials and Methods

2.1. Participants

A total of 32 male handball referees from Croatia were tested in this study—all elite referees (100% sample) from the highest rank of competition in handball in Croatia. Referees officiate in handball in pairs, and they are on the list of their national association and delegated in pairs for official matches. Subjects are selected every year according to their grades during the previous season and the completeness of all preseason tests which have

elimination criteria. Referees average age was 34.66 ± 6.44, height 184.02 ± 5.87 cm, body mass 91.14 ± 10.61 kg, body fat 19.20 ± 3.94% and body mass index 26.91 ± 2.47 kg/m^2.

2.2. Variables Sample

Morphological characteristics describe the structure of an athlete's body considering anthropometric measures which were measured in accordance with the standard International Biological Program (IBP) protocol:

1. Measurements of longitudinal skeleton dimensionality (body height)
2. Measures of volume and body mass (body mass)
3. Measures of subcutaneous fat tissue (skin folds with calliper: upper arm, back, chest, abdomen (abdominal skin fold), suprailiocrystal, upper leg and axillary).

After measurement, the composition of the body is calculated according to the curvilinear quadratic model proposed by Jackson and Pollock [23] (referred to as BD) to predict body density, as given by:

$$BD = a - b \times S + c \times S^2 - d \times age$$

where a = 1.1200000; b = 0.00043499; c = 0.00000055; d = 0.00028826, S = sum of 7 skin folds (upper arm, back, chest, abdomen (abdominal skin fold), suprailiocrystal, upper leg and axillary skin fold in millimetres); age—age in years.

The body fat percentage (referred to as BF) is commonly calculated from one of two formulas (ρ represents density in g/cm^3): Brozek formula: BF = $(4.57/\rho - 4.142) \times 100$. Siri formula is: BF = $(4.95/\rho - 4.50) \times 100$. In this paper, the Brozek formula was used [24] for obtaining a percentage of body fat.

4. Measures of obesity assessment (body mass index): body mass ratio in kilograms and squares of body height expressed in square meters:

$$\text{Body mass index} = \frac{\text{Body mass (kg)}}{\text{Body height (m)}^2}$$

The criterion variable is the evaluation of referees' performance during a match which is calculated through an official refereeing report from the Croatian Handball Referees Association. Supervisors are only competent to evaluate referees' performance in official matches as former referees with severe experience in the highest level of competition. This evaluation will be called quality of refereeing in the remainder of the article. Quality of refereeing is the average of all grades recorded by supervisors during one season, which is the sum of all grades during the season divided by the number of matches during a season. Grades are collected by supervision carried out during the entire handball match by the referee supervisor/match delegate. During the season many supervisors (always different supervisors for referees) are collecting grades for the referees and their average grade is the result of many supervisors' observations and gradations of all the matches in the season. In the final report which has the final grade, the referee supervisor, who is a referee expert due to his long-term referee and supervisor experience (minimum 15 years of active referee/delegate/supervision career) only in the highest rank, records the entire situation on the field and all the moves and decisions of the referees. There are 14 elements in the report based on which referees are evaluated: progressive punishment, seven meters, attacking foul, play on the goalkeeper's area line, enforcement, steps, passive play, unregular goal, advantage play, personality, understanding of the game and match management, signalling, movement and positioning and cooperation with the official desk. According to the number of mistakes, supervisors give the referees a grade − -, −, 0, +, ++, +++ (2 minuses, 1 minus, 0, 1 plus, 2 pluses and 3 pluses), where each has a separate meaning based on the number of mistakes during the match and points deduction. At the

end, the grades are added up and the maximum number of points is 100. Based on the average sum of points of all matches in the season, a ranking list of referees was created.

$$\text{Quality of refereeing} = \frac{\text{Sum of all grades in season}}{\text{Number of matches in season}}$$

2.3. Procedure

The study was approved by the ethics committee of the Faculty of Kinesiology, University of Zagreb. The whole study was undertaken in accordance with the ethical standards of the Helsinki Declaration and all the participants signed an informed consent expressing their willingness to proceed with all the testing for this research. Testing was performed in two parts which included two different venues. The first part of the testing was performed in the Diagnostic Centre of the Faculty of Kinesiology in Zagreb where morphological characteristics were measured in standard laboratory conditions. All measurements were conducted by only one doctor of sports science with many years of experience working as an expert in diagnostics in sports. Although their experience and education are certain, some of the measurement techniques such as measuring subcutaneous fat tissue using skinfold callipers have the possibility of human error and could be considered as one of the limitations of this study. The second part was conducted at different venues for official matches from the Croatian Premier Handball League. Referees were evaluated during the match by official delegates of the Croatian Handball Referees Association who gave an evaluation of referees' performance during the match.

2.4. Statistical Analysis

Statistical software Statistica (ver. 13.4., StatSoft GmbH, Hamburg, Germany) was used for statistical analysis. Central and dispersion parameters, arithmetic mean (AM) and standard deviations (SD) were calculated for morphological characteristics variables. Kolmogorov–Smirnov's test was used to check the normality of distribution and the maximum deviation of the empirical and theoretical relative cumulative rate (Max D). The correlation of morphological abilities (independent variables) and quality of refereeing (dependent variable) was tested with a multiple regression analysis test and the level of significance was set at $p < 0,05$. Pearson's correlation coefficient was used to determine the correlation between the overall experience in refereeing, the experience in refereeing at the highest ranks, age, and the quality of refereeing.

3. Results

Table 1 shows basic descriptive parameters of morphological characteristics which had been measured in the laboratory. In this study, 32 subjects had an average age of 34.29 ± 6.20 years. The youngest examinee was 24 years old, while the oldest was 45 years old. The subjects had an average body height of 184.46 ± 5.78 centimetres with the lowest at 174.3 centimetres, while the highest had 196.4 centimetres. The average body mass was 91.73 ± 10.57 kilograms (71.7 kg as the minimum and 109.8 kg as the maximum value, indicating a range of 38.1 kg). The average percentage of body fat in the body was $19.20 \pm 3.94\%$ with the lowest percentage of fat of 11.8% and the highest fat of 29.07%. The average body mass index was 26.91 ± 2.47 kg/m^2. Values of skewness and kurtosis distribution indicate the normal distribution of the results in all variables.

Table 1. Descriptive statistical parameters of morphological characteristics variables.

N = 32	AM	MIN	MAX	SD	SKEW	KURT	MAX D
Age (years)	34.29	24	45	6.20	0.32	−0.94	0.13
Height (cm)	184.46	174.3	196.4	5.78	0.20	−0.46	0.09
Mass (kg)	91.73	71.7	109.8	10.57	−0.23	−0.69	0.10
Body fat (%)	19.20	11.80	29.07	3.94	0.13	0.32	0.09
BMI (kg/m^2)	26.91	22.86	32.18	2.47	0.47	−0.51	0.13

In Table 2, a coefficient of a simple correlation is 0.05, while the coefficient of determination of 0.00 and a custom coefficient of determination cannot be displayed at a significance of 0.75. The default error prognosis is 3.95. The standardized regression coefficient of the variables for estimating the percentage of body fat measured on 7 skin folds is -0.06 with a coefficient of significance $p = 0.75$. Based on the results of the regression analysis ($p = 0.75$), it is concluded that there is no statistically significant correlation between the percentage of body fat of referees and the quality of refereeing.

Table 2. Results of regression analysis—influence of body fat percentage on the quality of refereeing.

$R = 0.05/R^2 = 0.00/$Adjusted $R^2 = $ —$/F(7,21) = 0.09/p = 0.75/$Standard Error Estimation = 3.95						
N = 32	Beta	Std.Err. of B	B	Std.Err. of B	t (21)	*p*-level
Intercept			**71.82**	**3.93**	**18.26**	**0.00 ***
%UFT 7	-0.06	0.19	-0.06	0.20	-0.31	0.75

Legend: %UFT 7—Under fat tissue expressed in percentage.

According to the Pearson coefficient of correlation, age is statistically significantly correlated with total experience (r = 0.73) and experience at the highest level (r = 0.61). The total experience is, apart from the already mentioned correlation with age (r = 0.73), statistically significantly correlated with the experience at the highest level (r = 0.85). The only statistically significant correlation (Table 3) with quality of refereeing has a variable experience at the highest level (r = 0.62).

Table 3. Correlation matrix between age, total experience, experience at the highest level and the quality of refereeing.

N = 32	Age	Total Experience	Experience at Highest Level	Quality of Refereeing
Age	1.00	**0.73 ***	**0.61 ***	0.23
Total experience	**0.73 ***	1.00	**0.85 ***	0.30
Experience at highest level	**0.61 ***	**0.85 ***	1.00	**0.62 ***
Quality of refereeing	0.23	0.30	**0.62 ***	1.00

4. Discussion

Some of the most important components of anthropological features for handball are the values of some morphological characteristics [22]. For the players, as well as for handball referees, a significant proportion of the selection process makes morphological characteristics. It is very important for handball referees to meet pre-determined body mass standards that are determined by age and height during the annual and semi-annual official seminars. In these norms, the percentage of body fat should be included in all federations to obtain a more accurate insight into the morphological characteristics of the body. They describe the body composition by observing many anthropometric measurements. The only morphological characteristic in this paper which almost certainly cannot be influenced by the training process is height. Since the height of the body does not have a significant impact on the quality of the refereeing, it is necessary to focus on programmed strength and conditioning training to optimize the muscle mass and fat percentage in the body.

Considering the evolution of handball, where motor and physiological demands are increasing during the match, a higher percentage of body fat may adversely affect almost all relevant abilities for success in handball. Consequently, this also may affect the quality of refereeing. As cited in the introduction, a negative link was found between higher body fat levels with levels of motor or functional abilities such as speed, explosiveness, coordination, agility, and aerobic and anaerobic capabilities. Several of these components could be

the deciding factor that could determine the result of the match. Agility, coordination, speed, and functional abilities can influence the movement of referees, and with reduced movement, referees cannot follow events and action on the pitch from a close distance. The distance of the referees from the events on the pitch is extremely important, as well to make a proper decision which depends on the position on the pitch where the event occurred, the time in the match and the physical condition of the referee [25–28]. From another point of a view, excessive distance from the events which happen at the stage in the match when reduced physical ability (fatigue) increases, the bigger the risk is of making the wrong decision as the visibility is not sufficiently clear [29,30]. Referees who have a significantly high amount of body fat cannot follow the demands of the modern game. Consequences of that are a lower quality of refereeing than physically fit referees, which is inappropriate and must be avoided as one wrong decision can have a direct impact on the outcome of a match.

Although in lower league referees can compensate for lack of physical preparation with their experience, at the international level and at higher level leagues this is no longer possible. The average body fat of subjects was 19.20 ± 3.94. Given the age of the subjects, numbers show that the subjects still have an optimal percentage of body fat (Figure 1), but are close to the limit of excessive body fat. The lowest percentage of fat in the body is 11.80%, which is very good, while the highest percentage is 29.07 which indicates obesity. This percentage of body fat is inadequate even for the normal adult population. Research on the nutritional intake of elite football referees [31] claims that the diet of referees is too saturated with fat and too caloric with the lack of essential vitamins and fibres. The excessive fat percentage in the body of referees negatively affects their functional and motor skills, and the non-professional appearance of the referee does not leave a positive and authoritative impression on the players. The result of this appearance is difficulty establishing authority over players, officials and supporters during the match.

Figure 1. Range of body fat according to categories [32]: 18, 19, 20 to 39, 40 to 59, 60—age range; 1, 2, 3, . . . 50—percentage of body fat.

The average calculated value of the examinees is 26.91 kg/m², with an average height of 184.46 cm and an average body mass of almost 92 kg, places handball referees in the population with excessive body mass. A similar population of first-league Hungarian referees had a BMI of 25.1 ± 2.3 kg/m² which is lower than in this study and very close to 25 kg/m² (obesity border), and their average height and weight are lower (179.6 ± 8.9 cm and 81.5 ± 13.6 kg) [33]. This data cannot be considered relevant because body mass index is calculated only based on data of body height and body weight. Regarding referees' work, which is regularly physically active through training and matches, the muscular mass of handball referees is higher than in the general, physically mostly inactive, population. This is the reason for higher body mass index compared to the results of body fat because higher muscle mass gives a higher body mass index [34,35] in overall results (Table 4).

Table 4. Frequency of subjects in variable body fat and body mass index.

Body Fat Percentage	Subjects from Age 20 to 39	Subjects of 40 +		Total
Underfat	0	0		0
Optimal	16	6		22
Overfat	7	1		8
Obese	1	1		2
Body mass index	**170–180 cm**	**180–190 cm**	**>190 cm**	**Total**
Malnutrition	0	0	0	0
Ideal weight	3	5	5	13
Excessive weight	2	10	2	14
Obesity	2	3	0	5

　　　The morphological characteristic of body fat does not have an influence on the quality of refereeing (Table 3). Considering that the referees on average have optimal body fat and relating to the existing elimination criteria which they need to pass on official seminars, referees cannot have a higher percent of body fat and this is the reason why differences between the subjects are not high. Most of the referees have optimal percentages of body fat (Table 4), while those with excess body fat do not deviate significantly from the optimal limit. According to this the hypothesis with the assumption there is a statistically significant negative correlation between a higher percentage of body fat and a lower quality of refereeing cannot be accepted. If there would be no criteria for official seminars and referees would have a higher range of results, there would be a higher possibility that the hypothesis could be accepted. Since the above-mentioned criteria only consider the height of the body and on this basis determine the permitted body mass, it is considered that the subjects with increased muscular mass are discriminated against.

　　　Using correlation analysis, a statistically significant correlation was found between age, total experience and experience at the highest level with the quality of refereeing. The experience of refereeing at the highest level is statistically significant correlated ($r = 0.62$, $p < 0.05$) with the quality of refereeing. Firsthand experience is very important in refereeing along with early specialization in sports [36], where a future referee familiarises themself with the rules of sport through practising it or watching sports from the perspective of the viewer (collecting visual–motor experience). Experience is one of the most important elements of refereeing as a skill, and this is precisely the conclusion of Gündoğdu et al. [37] and Weston et al. [38], that senior referees are quality-wise better, and they are ranked more successfully in the rankings than younger colleagues. Refereeing cannot be practised at training [39], the skill of refereeing is acquired by experience, feeling of play and a great number of repeated sport-specific situations that occur during matches, because refereeing is unpredictable with a lot of new situations and almost always with different outcomes. Given the selection of referees and progress through the years of refereeing, only the best referees can be promoted to the highest ranking. High stake matches are very stressful and very demanding, and only referees who are experienced and physically ready can officiate with minimum risk of making cardinal errors. In order to be successful, referees must be very stable and impartial persons, not subjected to pressure and irrational emotions and with an extremely high threshold of self-control and authority towards all participants in a competition. That is exactly the skill that is learned and perfected by experience, especially in the most difficult matches which are mostly in the highest rank of the competition. Among the referees, there are differences which reduce with years and experience, but if the referee does not have other skills relevant for success in refereeing, they cannot be a high-ranked referee having only experience as their quality. It is very debatable if such a referee could come to the list of the highest rank in his national association after all elimination and evaluation criteria during the years, and especially on the lists of international federations where only the best referee couples from the national federations have the chance to officiate the most important international matches.

5. Conclusions

It cannot be claimed that the existing elimination criteria (measurement of morphological characteristics and functional abilities at official tests) that referees must satisfy at official seminars, before the beginning of the season and in the middle of the season, should be abolished or that they are insufficient. Precisely because these criteria exist, referees are already a selected population that is homogeneous, and the variability of that sample is low. If there were no elimination criteria at official seminars, there would have been greater variability among referees and it would be possible to confirm the hypothesis that body fat has an impact on the quality of the refereeing. Based on these facts, it is concluded that the existing selection of referees is good and there is no great variability among them, considering their morphological characteristics.

Experience in refereeing is significant for the quality of refereeing, especially experience in the highest level of competition. This proves that refereeing is an extremely complex and very demanding and long process of training in decision-making skills. It cannot be trained, but it is a logical sequence of gaining experience through refereeing a large number of matches. In those matches, many non-specific situations occur where referees stereotypically learn and apply this knowledge later. Referees increase their quality in decision-making by experience, especially in the highest rank, which they can referee only with high evaluation grades over the years and by meeting the elimination criteria of body weight and physical fitness in official seminars. In future studies, it would be good to check whether referees from different ranks of competition would confirm the hypothesis because they are not as homogenous a group as the referees from the highest rank of competition.

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