THE INFLUENCE OF BODY HEIGHT, BODY WEIGHT, BODY MASS INDEX ON HAND GRIP STRENGTH FEMALE VOLLEYBALL PLAYER: PILOT STUDY

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Abstract
Reliable and valid assessment of hand strength is important for determining the effectiveness of various sports activities when the hands produce the appropriate muscle gripping force, which manifests as hand grip strength (HGS). The force of the handgrip is recognized as a limiting factor in all manipulative activities performed by the cranial part of the body. The current research included a sample of 18 volleyball players VC "Jahorina" East Sarajevo city (Body height = 173 ± 8.77cm; Body weight= 66.04 ± 9.09kg; Body mass index =22,03±2,19 kg/m²), of a member of the Premier League Bosnia and Herzegovina. The aim of the study was to determine the maximum isometric muscle strength of the handgrip depending on the Body height (BH), Body weight (BW) and Body mass index (BMI). Basic statistical parameters, Simple regression analysis and Pearson correlation matrix were applied for data processing. The obtained research results confirmed a statistically significant influence and correlations of all measured characteristics on Hand Grip Strength ($p<0.05$; $p<0.01$), except BMI. The results confirmed a statistically significant influence of Body height on HGS (Pearson $r_{Right\ hand}=0.441$; $R^2_{Right\ hand}=0.294$; $p=0.047$; Pearson $r_{Left\ hand}=0.534$; $R^2_{Left\ hand}=0.286$; $p=0.022$) and Body weight (Pearson $r_{Right\ hand}=0.573$; $R^2_{Right\ hand}=0.329$; $p=0.013$; Pearson $r_{Left\ hand}=0.688$; $R^2_{Left\ hand}=0.475$; $p=0.002$). The data presented in the study have a huge practical application and can be useful in future research on player selection, identification of talents in volleyball and development of training programs. The obtained research results will be used for analytical and diagnostic purposes of volleyball players in order to have a more efficient training and competition process.

Key words: anthropometrics, influence, volleyball, hand grip strength (HGS)

INTRODUCTION

Human hand has given humans their survival advantage and because of it, they have evolved better through the ages. Grasping is the feature that surpasses all functions that the human hand can perform (Khan, Junaid, Jamshed, et al. 2019). Based on this single function of gripping, sports physiologists classify the various varieties of sports into gripping and non-gripping sports. Basketball, volley ball, softball, wrestling, rock climbing, tennis, and javelin throw are some of the examples of gripping sports. Hand dimensions which include individual digit span, hand length, hand width as well as overall body strength all are inter-related and contribute significantly to the techniques applied in all of these sports (Fallahi, & Jadidian. 2011).

Muscle strength, muscle capacity and muscle endurance are the basic principles that define human muscle function, and hand grip strength is a relevant indicator of testing the total muscle strength of the arm (Foo, 2007) but also the overall physical strength of an individual (Massey-Vestrop, Rankib, Ahern, et al., 2004; Bohannon, 2001). According to Chandrasekaran, Ghosh, Prasad, et al. 2010) the strength of this manipulative human movement is common in clinical assessment for various musculoskeletal systems, neuromuscular disorders, and cardiovascular disorders. This strength test is important in monitoring both physical and social factors (Koley & Singh, 2010; Gallup, O'Brien, White, et al. 2010; Hossain, Zyroul, Pereira, et al., 2012). In many cases, a strength test is a recipe for rehabilitation from injuries (golf and tennis elbow) that are often caused by an incorrect balance of strength between the upper arm muscles and the forearm muscles so their uneven tension accumulates in the soft tissue and results more severe elbow pain. Everyday physical activities involve contractions of the forearm muscles, so hand grip strength appears as a limiting factor of various sports performances (Balas, Kodejška, Krupková, et al., 2020). Due to this fact, in many physical and individual sports activities the measurement of grip strength is recommended and reliable as the primary approach for measuring muscle function (Beaudart, Rolland, Cruz-Jentoft, et al., 2019). According to Koley, & Pal Kaur (2011) grip strength is the result of the flexion force of all finger joints with the maximum voluntary force that a subject is able to perform under normal biokinetic conditions using several muscles in the hand and forearm. Participates in manipulative activities of the cranial part of the body, defining physiological variables affected by age, sex, body size, level of training, type of sports activity, so hand strength is considered one of the most important and best indicators of morphological-functional, health and nutritional status. (Chilima, & Ismail, 2001; Pieterse et al., 2002; Carreira, Amaral, Brás-Silva, et al., 2010; Musa, Li, Xiaoshan, Guo,

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et al, 2018). During the life cycle, the strength of the grip progressively increases, reaching a peak around the age of 35, and then progressively decreases, as a result of reduced muscle cross-section and various degenerative changes in joints and reduced bone density (Dixon, Lunt, Pye, et al. 2005; Gunther, Burger, Rickert, et al. 2008). In middle age, grip strength can predict a decrease in physical ability in old age and be used as a screening tool to assess cranial body strength, while its reduction in men leads to increased mortality from cardiovascular disease and cancer (Gale, Martin, Cooper, and sar 2007; Ruiz, Sui, Lobelo, et al.2008). Lower values of physical ability have been shown to be associated with a higher risk of subsequent health problems, where poorer grip strength and slower walking speed are associated with an increased risk of bone fractures, cognitive decline during aging, and assessment of treatment outcomes (Frederiksen, Gaist, Petersen, et al. 2002; Cooper, Kuh, & Hardy, 2010).

The characteristics of HGS are relatively predictable and are directly correlated with morphological structure, degree of training, health and physiological condition at the time of testing. High correlations between HGS, physical and anthropometric parameters are confirmed by various studies (Häger-Ross & Rösblad, 2002; Luna-Heredia, Martín-Peña, & Ruiz-Galiana, 2005; Jürimäe, Hurbo, & Jürimäe, 2009; Shymal, & Satinder, 2011; Massy-Westropp, Gill, Taylor, et al., 2011; Koley, & Kumaar, 2012; Hossain, Zyroul, Pereira, et al. 2012; Pavlović, Savić, Radulović, et al. 2021) whose application is manifested in numerous activities, both among recreational athletes and top athletes (Koley, & Singh, 2002; Ivanović, Koropanovski, Vučković, et al. 2009).

The strength of the grip of the right and left hand is positively correlated with weight, height and body surface, so from the aspect of cybernetics in sports, development of control methods and assessment of physical abilities, it is necessary to define models for assessing the actual state of development of a given limb and muscle group. determine their performance (Pavlović, & Vrcić, 2021). Some authors (Müller, Benko, Raschner, et al. 2000) investigating the maximum isometric force and its dimensions have defined the basic characteristics of the model at maximum isometric grip for analytical and diagnostic purposes of athletes (Guidetti, Musulin, Baldari, 2002; Giles, Rhodes, Taunton, 2006; Leyk, Gorges, Ridder, et al. 2007). Certain studies show that arm strength is an important component in volleyball, basketball, handball, tennis, weightlifting, bowling, baseball, wrestling, Nordic running, etc. (Tan, Aziz, Teh, et al. 2001; Wassmer, & Mookerjee, 2002; Lucki, & Nicolay, 2007; Melrose, Spaniol, Bohling, et al. 2007). Interest in the anthropometric characteristics and body composition of various athletes has grown over the last decades. Among them, the physical abilities of the players are more important because they have pronounced effects on the skill of the players and the tactics of the teams, because ball games require repeated maximum effort, such as run and jump (Tsunawake, Tahara, Moji, et al. 2003).

In this regard, anthropometric characteristics play an important role in determining the success of athletes. Available information regarding the correlations of anthropometric variables (height, weight, arm span, forearm circumference, upper arm circumference) and volleyball arm strength has not been published so far, in fact, arm strength has been established only as an indicator of the total individual physical strength (Foo, 2007). Volleyball is a sports game that requires comprehensive abilities (physical, technical, mental and tactical) with maximum use of cranial extremities. The fact is that the arms do not function in isolation and depend on the integration of the shoulder and elbow complex in order to enable adequate positioning of the arm in space in order to complete the desired movement (Barut, Demirel, & Kiran, 2008). In volleyball, the choice of players is most often based on skills, level of performance and muscle strength. Players also need specific characteristics and abilities specific to volleyball elements such as height, agility and performance of technical and playing movements. (Anza, Denis, Silva 2013). According to Faraja, Sarvari, Atri (2014), volleyball requires an appropriate level of strength in the hands to maximize control and performance in the sport. According to our information, there was no research in women's volleyball in the BiH Premier League that studied this issue of hand grip strength and correlation with anthropometric characteristics. The aim of the present study was to evaluate the effect of Body height, Body weight and anthropometric characteristics of the upper limbs on hand gripe of elite, female volleyball players VC "Jahorina". This is the first research with the population volleyball female players that will give an adequate answer to the defined goal of the research.

METHODOLOGY

The sample of participants

The cross-sectional study included a sample of 18 female volleyball players, the members of the VC "Jahorina" from Pale, East Sarajevo city (Body height=173±8,77cm; Body weight=66,04±9,09kg; BMI=22,03±2,19 kg/m², age 19,11±2,63 years old) who competes in the Premier League of Bosnia and Herzegovina. All the players participants were healthy and physically fit with no history of injury in the past six months. The participants were informed in detail about the nature of the study and investigational procedures, and all the players participants have voluntarily given their consent to be the part of this study. The inclusion criteria were that there was no restriction of movement in the upper extremities, inflammatory joint diseases or neurological disorders. No participants reported ambidexterity. The research was conducted in accordance with the professional and ethical standards of the Declaration of Helsinki

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HGS Testing Procedures

The muscular force of the flexors of the fingers of the hand was measured by the method of isometric dynamometry in laboratory conditions where a standardized test - Hand grip was used. The testing procedure was conducted in accordance with the defined recommendations of the American Society of Hands Therapists-ASHT. The force realized at maximum hand grip (dynamometry) was measured using a digital hand dynamometer CAMRY-EH101, USA. Dynamometry of the hand was performed by holding the subject dynamometer in one hand (bent at the elbow joint at 90°) while the other hand was resting on the thigh. The subject was then instructed to squeeze the dynamometer as tightly as possible, using the musculature of the hand. He tried to achieve the best possible result with the maximum strong grip. Each subject performed two attempts with a stronger and weaker hand, and as relevant for statistical processing, a better result was recorded. The results are expressed in kilograms (kg) with a measurement accuracy of 0.01 kg. Calibration of the instrument was performed periodically during the study.

Picture 1. CAMRY- Digital Hand Dynamometer, 200lb, EH101, USA

Statistical analysis

In the research study, Body height, Body weight, BMI, Arm span, Upper arm perimeter, Forearm perimeter were defined as an independent variable (predictors), while the results hand grip strength of (criteria). First, the central and dispersion parameters were calculated for all anthropometrics parameters (AP). The normality of the distribution of results was determined by Kolmogorov-Smirnov normality test (K-S test). Pearson correlation coefficient (Pearson r) was used to determine the relationship between AP and the results of Hand Grip Strength (HGS). The obtained correlations are presented in tables and figure. In order to more accurately confirm the results defined by the research goal and to determine the influence of anthropometrics parameters on the result hand grip performance. A simple model of regression analysis (R^2) was applied, and the relevant coefficients were calculated. The level of acceptance of statistical significance was set to $p<0.05$. The statistical package STATISTICA, version 10.0 (STA999k347150-W) was used for data processing.

RESULTS

Table 1 contains the basic statistical parameters of HGS for samples. The average maximum HGS with the right hand of volleyball players was 33.87±5.03kg, and with the left it was 30.89±5.69kg. The minimum HGS achieved with the right hand is 23.80kg, and the maximum is 39.40kg in the range of 15.60kg. The maximum achieved HGS of volleyball players with the left hand is 39.50kg, and the minimum is 22.10kg in the range of 17.40kg. The results of the regression function showed significant correlations between anthropometric parameters and HGS. Medium-high correlations of Pearson's coefficient and regression coefficients for both hands were recorded (Table 1). Body weight proved to be the leading factor influencing the grip strength of the left arm ($r = 0.688$; $R^2 = 0.475$; $p = 0.002$) and the right arm ($r = 0.573$; $R^2 = 0.329$; $p = 0.013$). Also, body height was statistically significant in predicting the strength of the right hand grip ($r = 0.441$; $R^2 = 0.294$; $p < 0.047$). BMI did not show a significant impact (Figure 1-4).

Table 1. The statistics parameters

Hand grip	Mean±SD (min.-max.)	Range	CV%	K-S	Parameter	Pearson (r)	Simple regression analysis			
							R^2	Adj.R^2	F	p<0.05

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Right hand (kg)	33.87±5.03 (23.80-39.40)	15.60	14.88	0.224	BH (cm)	0.441	0,294	0,244	3,860	0,047
					BW (kg)	0.573	0,329	0,287	7.848	0.013
					BMI (kg/m²)	0.351	0,124	0,069	2,261	0,152
Left hand (kg)	30.89±5.69 (22.10-39.50)	17.40	18.43	0.103	BH (cm)	0.534	0,286	0,241	6,409	0,022
					BW (kg)	0.688	0,475	0,442	14,46	0,002
					BMI (kg/m²)	0.414	0,172	0,120	3,317	0,087

Note: *p<0.05

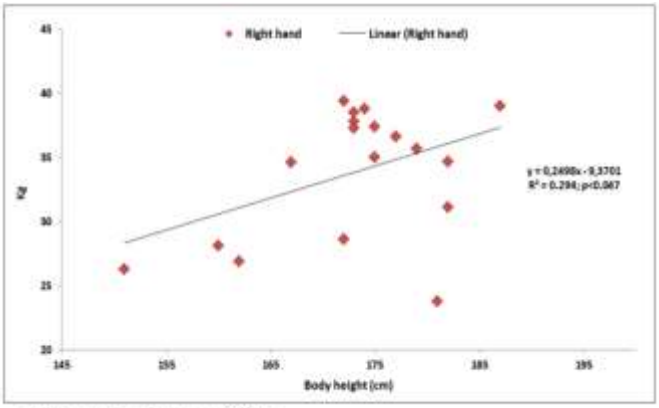

Figure 1. BH vs. $HGS_{Right\ hand}$

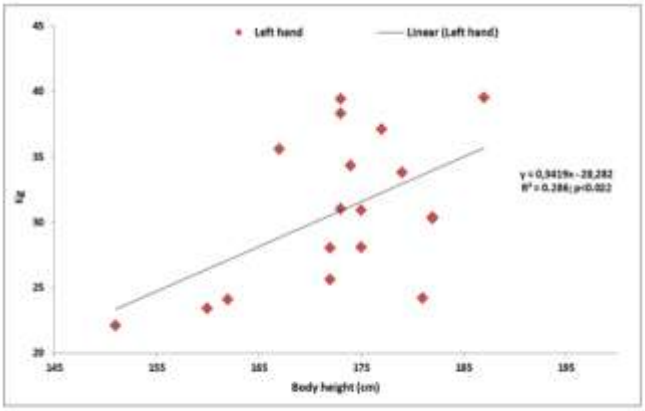

Figure 2. BH vs. $HGS_{Left\ hand}$

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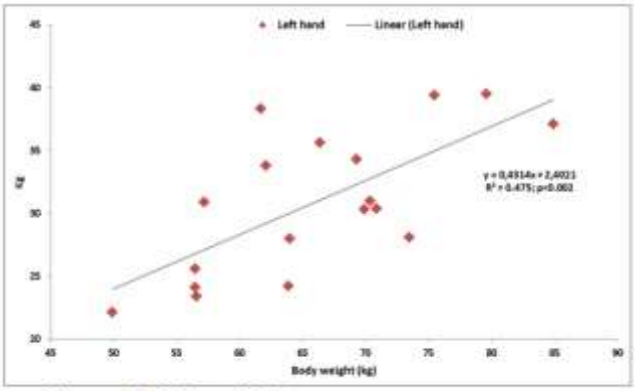

Figure 3. BW vs. $HGS_{Left\ hand}$

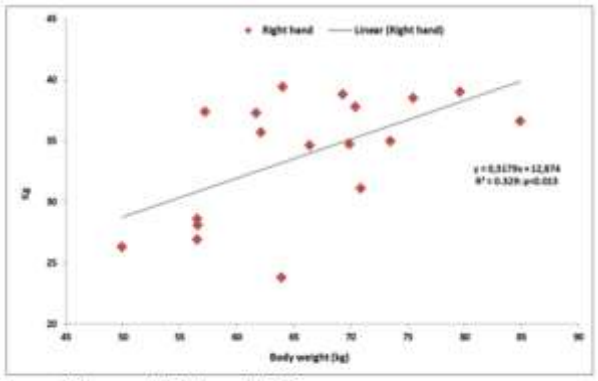

Figure 4. BW vs. $HGS_{Right\ hand}$

DISCUSSION

The aim of this study was to examine the influence of body height, body weight and BMI on the muscle characteristics of the grip strength of the volleyball player Jahorina, a member of the BiH Premier League. Results were obtained that show a significant influence of body height and body weight ($p < 0.05$), on the grip strength while BMI recorded a positive linear function but without statistical significance.

Testing and assessment of grip strength is applied in different areas of sports disciplines, and a large number of studies define the use of hands in different sports, both for recreational athletes and top athletes. (Ivanovic, Koropanovski, & Vuckovic, 2009). Volleyball is a specialized sport with specific anthropometric, physical performances, so the choice of such players is mainly based on their skills, performance levels, physical and muscular strength. (Benetti, Schneider, & Mezer, 2005), Duncan, Woodfield, & Al-Nakeeb, 2006)**.** Some studies (Gualdi-Russo, & Zaccagni, 2001.) show that players, in addition to adequate anthropometric characteristics, possess exceptional muscular strength, explosive strength, strength and height in blocking, jumping speed, endurance and agility**.** In volleyball, it is characteristic that teams compete in manipulating the ball above the head (passing and rebounding the ball with the fingers, hand), so height is considered the most important physical attribute. Higher values of body height in players can be attributed to the fact that elite volleyball players are required to have a pronounced height and strength in the wrist and fingers due to the nature and type of sport. Thus, a higher height for players provides an advantage in that they can reach over the top of the net as well as performing offensive and defensive actions over the net **(**Saroha, & Pathak, 2016).

It is the results of the current study that lead to the conclusion that body height and body weight have proven to be more important anthropometric variables in volleyball players. In other words, taller and heavier female volleyball players also have a stronger handshake, which is in line with the study (Faraji, Sarvari, & Atri, 2014). Jahorina volleyball players record higher average height and weight than their foreign counterparts from India (164.78±4cm i 58.16 ±5.54kg) (Koley, & Pal Kaur, 2011) and they are lower and lighter than the American ones (176,70 cm, ± 4,60 i 69,70 kg ± 10,80). Ferris, Signorile, & Caruso (1995) and Turkish players (174,00 cm, ± 7,60 i 61,1 kg ± 8,70) (Belgin, Tuncay, Aydin et al.2003). The distribution of current results defined in this way is a consequence of the morphological status of volleyball players, where body weight, height, individual longitudinal proportions, muscle structure are sometimes defined as a decisive factor in the strength of hand grip. (Musa, Li, & Xiaoshan, 2018). In the field of anthropometric measurements, grip strength characteristics are often compared and correlated with other physical characteristics, e.g. body height, weight, BMI and age. Some anthropometric variables (forearm circumference and length, arm size, body weight) show a positive correlation with grip strength, which is present in our study, while body mass index, show only a partial positive correlation with grip strength (Günther, Burger, & Rickert, 2008). Hand grip characteristics are relatively predictable because they are directly related to morphological structure, training, fitness, health, and physiological condition at the time of testing. According to Khanna, & Koley (2020) regular training of volleyball female players increases muscle mass which, along with height and body weight, increases grip strength.

The maximum strength of the grip of our volleyball players with the right hand is 33.87 kg, and with the left 30.89 kg, which is a higher strength compared to previous studies on the same population. (Barut, Demirel, & Kiran, 2008; Koley, & Pal Kaur, 2011, Faraji, Sarvari, & Atri, 2014; Kaplan, 2016) and in accordance with the results of the study Khanna, & Koley (2020). In the case of grip strength of the right and left hand, as indicators of physical performance, with height,

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weight, medium-high correlations were found in our volleyball players, which is in line with the results of previously published studies in different populations (Häger -Ross & Rosblad, 2002; Luna-Heredia, Martín-Peña, Ruiz-Galiana, 2005; Jürimäe, Hurbo, & Jürimäe, 2009; Shiamal, & Satinder 2011; Massy-Westropp et al., 2011; Koley, Kumaar, 2012; Hossain, Zyroul, Pereira, & Kamarul, 2012). It turns out that the current study follows the same line, showing a good and significant positive correlation with the right and left hand.

The arms (hands) are anatomically predetermined for various manipulative tasks, producing appropriate muscle hand strength grip during various physical and sports activitie, while optimal arm function includes maintaining the amplitude of movement in all joints of the upper extremities, contractile ability of muscles, endurance and grip strength function. Due to this fact, in many activities the measurement of grip strength is recommended and reliable as the primary approach for measuring muscle function (Beaudart., Rolland, Cruz-Jentoft, et al 2019). On this fact was the choice of our research. Hand grip testing is indicative of general muscle strength, as in adults grip strength is associated with arm, back, and leg strength (Fricke, & Schoenau, 2005; Wang, Leger , & Dumas, 2005) which is extremely important in volleyball, which involves a large number of jumps, landings, blocking online. In these situations, the strength of the hand is important, which performs amortization (landing), hitting (spike) or pushing the opponent on the net (blocking). In our study, the dominance of right-handed women in relation to left-handed volleyball players is noticeable, which is supported by previous research on this topic. (Melrose, Spaniol, Bohling, & Bonnette, 2007, Ertem, Inan, Yologlu, et al. 2003). Partial differences in right and left hand grip have been supported by previous studies (Ertem, Harma, Cetin, et al. 2005) where the dominant hand is stronger than the non-dominant one (do 3%), which is in line with our results.

The distribution of the results of our study supports the results that imply that the strength of the dominant arm is greater than the strength of the non-dominant by about 10%. Similar results that are in line with our study were found in other authors (Häger-Ros., Rösblad, 2002; Jürimäe, Hurbo, & Jürimäe, 2009; Koley, & Kumaar 2012) where the strength of the hand grip is a consequence of a different anthropometric profile which contains both the different muscle structure and the nutritional status of the individual. The strength of the grip significantly defines the mineral content in the bones and bone surfaces on the forearms, which is positively correlated with the active body weight and physical activity of volleyball players, which is in line with the results of the current study, where the sample consists of physically active women. In this regard, the appropriate contractile characteristics of grip strength are an indicator of the developmental ability of the basic active functional limb (arm), which is an anatomically specialized organ of the end of the kinetic chain (Hossain, Zyroul, & Pereira, 2012; Luna-Heredia, Martín-Peña Ruiz-Galiana (2005). Muscle strength is an important aspect of physical fitness and health, where any decrease in muscle strength causes significant functional limitations in sports (Wind, Takken, Helders, & Engelbert, 2000) and so did volleyball.

This is the first research on this topic with a female's volleyball club in the BiH Premier League. The next study included a significantly larger number of respondents (several BiH Premier League clubs), which would enable more significant conclusions to be drawn.

CONCLUSION

The research included the female volleyball players of VC "Jahorina" Pale, East Sarajevo city, with the aim of assessing the influence of Body height, Body weight and BMI on the results of HGS. The obtained research results confirmed a statistically significant influence of Body height on HGS (Pearson $r_{\text{Right hand}}=0.441$; $R^2_{\text{Right hand}}=0.294$; $p=0.047$; Pearson $r_{\text{Left hand}}=0.534$; $R^2_{\text{Left hand}}=0.286$; $p=0.022$) and Body weight (Pearson $r_{\text{Right hand}}=0.573$; $R^2_{\text{Right hand}}=0.329$; $p=0.013$; Pearson $r_{\text{Left hand}}=0.688$; $R^2_{\text{Left hand}}=0.475$; $p=0.002$).

It can be concluded that the strength of the hand grip had strong positive correlations with the height and weight of the volleyball players. The data presented in the studie have a huge practical application and can be useful in future research on player selection, identification of talents in volleyball and development of training programs. The obtained research results will be used for analytical and diagnostic purposes of volleyball players in order to have a more efficient training and competition process.

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