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Original Research

The Investigation of Compressive Force in the New Designed Beta Volleyball to Prevent Sport Injuries

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Abstract

Background: One of the main causes of sports injuries is related to sports equipment and the type of ball. Thus, the purpose of this study is to investigate the compressive force of the new designed Beta volleyball to prevent upper limb injuries among volleyball players.

Methods: The present study is an applied and laboratory study. To investigate the compressive force of the new designed Beta volleyball and compare the balls to each other, Bertek force plate were used.

Conclusion: Results showed that there was significant difference between the softness of the new designed Beta volleyball compared to fox and old Beta volleyballs in peak compressive force ($P = \leq 0.001$). But there was no significant difference between the newly designed ball and the standard Mikasa ball ($P = 0.72$).

Keywords: New Designed Volleyball,Sports Injuries, Compressive Force

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Introduction

Sports injuries are considered among the most common injuries in western societies. Volleyball, handball, basketball, and football are among the high-injuries ball sports (1). Injury is an inevitable part of sports, specifically ball sports. Various parts of the body are exposed to injuries while playing sports. These damages are the result of collisions between players with each other, the floor, or related to the sports equipment (2). Sports balls used in volleyball could result in hand injuries in players playing this sport. The use of hands to control sports balls during training and matches and the contact between sports balls and various surfaces of fingers make for hand injuries. Managing finger injuries in sports players is usually a great challenge to hand surgeons (3).

The nature of some sports fields results in more damages to athletes playing those sports, particularly in certain parts of their bodies (3). Many of the skills practiced in volleyball such as serve, spike, and defense on the net require constant contact between the ball and the athlete's hands (4). The main purpose behind spikes in volleyball is to hit the ball with maximum speed which could be quite hard since transferring the maximum velocity to the ball results in angular velocity and internal shoulder joint rotation to reach a maximum of 4,000-7,000 per second (5). Thus, experienced volleyball players put too much tension and pressure on their shoulder joints during matches or training sessions (5). Mallet finger is a prevalent injury in ball sports such as football, volleyball, and baseball (3) and is usually the result of hyper-flexion of the finger sliding across the ball or direct contact with other players. Middle and pinky fingers have the highest rate of injuries (6).

Hand bone fracture is common in many ball sports as well. For instance, breaking the metacarpal bone occurs as a result of direct and indirect blows and forces or excessive bending and twisting (7). There are several other bone injuries prevalently witnessed in ball sports (7). Fractures are usually categorized into intra-articular and extra-articular fractures. Extra-articular fractures can mainly be treated without dislocation using splints, while intra-articular fractures usually demand surgery and treatment (7). According to volleyball injury analysis, the area's most prone to injuries during volleyball include the upper limb with 71.30% and the lower limb with 21.50% of the injuries. Shjoaadin et al. (2008) have reported the number of injuries to upper limb out of total injuries to be 39.68% in volleyball players and 38.40% in handball players (2).

The advancement of sports equipment has revolutionized all sports matches and the work of engineers developing sports equipment to improve and increase athletes' performance as well as reduce the rate of sports injuries. Many of the advancements have occurred through the study of some major impacts concerning the development of sports equipment by engineering the materials used in manufacturing sports equipment (8, 9). Fiber-used composites resulted in the lightweight and highly resistant materials with unique design and properties, and are widely used in sports equipment (10).

Fiber-used composite materials have excellent elasticity levels and coefficient as well as resistance to make new sports equipment. Besides, these materials have the property of absorbing shocks which is one of the reasons for their use to produce sports equipment (10). In 1974, a study was conducted by the Chemold Company in the United States on medium-grade tennis rackets made out of carbon fiber composites. Several companies such as Chemold have been using carbon fiber composites that can improve both tennis rackets' performance and efficiency, and result in shock absorption since 1974. Designing tennis rackets using carbon fibers has advantages such as higher resistance, lighter weight, and shock absorption over other materials used before (11). Sport sciences engineers have designed sports shoes that provide more energy using Nano-materials (12). Brondsted et al. (2005) designed bicycle steel structures by attaching carbon fiber to aluminum in their study and developed a bicycle structure out of carbon fiber which is more resistant and lighter than light molybdenum chrome steel. After this technology was developed, it was used in bicycles in official competitions, too (10, 11).

Recent studies on sports balls have mainly addressed aerodynamic forces and the author found no research focused on the compressive forces that result in injuries. Thus, the present study aims to examine the compressive force of the new designed Beta volleyball using composites and new chemical materials reinforced with rubber materials used to make volleyballs to increase their softness and reduce the rate of sports injuries among volleyball players.

Methods and materials

The design and production of new volleyballs

The present study is an applied laboratory research seeking to examine the new design of volleyballs and compare it to other available volleyball balls. The materials used to make the bladder of sports balls have been changed to design and manufacture the new Beta volleyball aiming to increase its softness which results in reduced sports injury rates among volleyball players. The ball must be streamlined using panels to increase its strength and maintain the ball-shaped. The paneled bladder of the new Beta volleyball was covered with a special fabric instead of rubber from the third layer of the ball to increase its bounce.

Research inclusion criteria

The inclusion criteria of the present research included samples of size V5 volleyballs (the official competition size) weighing 265-270gr with an internal air pressure of 4 psi, a diameter of 66±1 cm, 60±66 cm bounce from a one-meter height resisting against the test of 2000 blows at the speed of 50km/h inside the impact tester for 12 hours with no deformity as Figure 1 indicates.

Figure 1- Sports ball impact testing machine

After the impact test was finished, all the samples inside the device were kept on shelves for 24 hours to make sure they had not been punctured.

Undamaged sample balls were measured using an advanced caliper model Asimeto made in China after 24 hours. The measurement method was various points of ball taken out of the impact tester were measured in 12 efforts as Figure 2 indicates.

Figure 2- The caliper used to measure the diameter of sample balls

Sample balls with nonstandard diameters according to FIVB standards (66±1 cm) were excluded from the study. An advanced bounce machine model juiyi made in China was used to examine the bounce of the balls as Figure 3 indicates. The method for measuring the balls' bouncing height was that all samples were thrown from a height of one meter in five efforts with an average bounce of 60±66 cm according to the Federation International Volleyball (FIVB).

Figure 3- The bounce test machine

The EB 9003 digital scale made by Tehran Kala Iran Company was used to weigh the samples. The measuring technique was that all samples that had passed the previous tests with no deformity were measured in kilograms. A digital pressure gauge made by Mikasa Company was used to measure the air pressure inside the balls. The measurement technique was that samples were measured under no external pressure or force in a free state as Figure 4 indicates

Figure 4- Measuring the air pressure inside samples

Measuring samples' softness using a force plate

Eventually, a Bertec force plate made in USA was used in the health center of Mohaghegh Ardebili University in five efforts under the same condition from a height of one meter to reduce the error of recording data when examining the compressive force of the new designed Beta volleyball and compared its softness to Mikasa, Fox, and old Beta volleyballs.

Figure 5- The Softness of the Samples Using a Plate Plate

Statistical Methods

Inferential and descriptive statistics were used to analyze collected data using the SPSS v.26 software with a significance level of $P \leq 0.05$. Data distribution normality was determined using the Shapiro-wilk test. One-way ANOVA and Bonferroni post-hoc test was used for within and between group comparisons.

Results

According to Table 1, results indicated that no significant difference was observed between the numbers of each of the four types of volleyballs deformed in the impact tester ($P = 0.85$). No significant difference was observed between the four types of volleyballs in terms of their bounce either ($P = 0.55$). In other words, one could say that the four types of volleyballs were similar and had no significant difference was observed among them in these regards according to the tests.

Table 1- The Four Volleyballs' Deformity and Bounce Mean and Standard Deviation

Parameter	Old BETA	FOX	SIG NEW BETA MIKASA
Deformation	0.792±65.91	0.753±65.73	0.796±66.90 0.750±64.78 0.850
Bounding	0.790±66.45	0.789±65.04	0.798±66.20 0.796±65.98 0.559

According to Table2, results of the present study indicated that there was statistically significant difference between the balls in terms of their peak compressive force in the FZ direction ($P < 0.001$).There is no statistically significant difference between four types of balls in time to peak compressive force in direction of FZ ($P = 0.42$).

Table 2- Mean and Standard Deviation of Asymmetry at Peak and the Compressive Point at the Peak Point in the FZ Direction

Parameter	Old BETA	FOX	SIG NEW BETA MIKASA
FZMax	620.35±17.778	573.80±10.785	478.57±41.824 395.99±46.936 p<0.001
TTPFZ	878.60±298.849	569.00±359.069	480.20±916.215 761.400±308.200 0.425

According to Table 3, The LSD Post Hoc test showed that there was a statistically significant difference between the peak of vertical force (FZ) of the new designed Beta volleyball and fox and regular Beta volleyballs ($P > 0.05$). However, there is no significant difference in the vertical force peak

(FZ) between new designed beta volleyballs and the Mikasa volleyball. According to the results of Table 3, Mikasa volleyballs are significantly different from old Beta and Fox volleyballs in terms of the peak compressive force in the FZ direction ($P < 0.05$).

Table 3: Difference Between Groups in Terms of the Peak Compressive Force in the Direction of FZ in Four Samples

Row	Compare between Groups		Sig
1	NEW BETA	OLD BETA	<0.001
		FOX	0.005
		MIKASA	0.725
2	OLD BETA	FOX	0.007
		MIKASA	<0.001
3	MIKASA	FOX	0.002

Discussion

The purpose of present study is to examine the compressive force of the new Beta volleyball using new chemicals and composites compared to Fox, Mikasa, and old Beta volleyballs using a force plate to prevent sports injuries among volleyball players. The results showed that there was no significant difference in the vertical force peak (FZ) between the two newly designed beta volleyballs and the Mikasa volleyball. Also, there was no significant difference in the time to peak of compressive force (FZ) in any of the samples.

Similar to the present study, the results of Kuizumi et al. (2014) obtained from examining the impulse force of Modern Jabluni2, Cafusa3, Teamgeast4, and Pilienist5 designed by Adidas. A kick-robot equipped with a dynamometer (a force plate) was used to compare changes in the impact characteristics of soccer balls from the viewpoint of differences in ball shape. The maximum impulsive force for Cafusa was less than that of the other balls. The results of that study are in line with the present study. The reason for the consistency of the results may be affected by the flexibility of the surface material and the inner reinforcing layer (middle layer). The impulse for Jabulani was greater than that of the other balls at all velocities. The reason for the consistency of

1. Soccer ball designed by Adidas, official FIFA 2010 world cup ball made out of eight triangular and fin panels
2. Soccer ball designed by Adidas; official FIFA 2013 confederation cup ball made out of 32 panels
3. Soccer ball designed by Adidas, official FIFA 2007 world league cup made out of 14 panels including 8 rotor and 6 butterfly panels
4. Soccer ball designed by Adidas, official Olympics 2004 ball made out of 32 panels including 12 pentagonal panels and 20 hexagonal panels

the results is presumably due to the characteristics of the surface material and the structure of balls (13).

Other research on sports equipment related to fluid dynamics, the aerodynamic characteristics of the ball, and the body material of the bicycle and badminton racket. Takeshi et al. (2020) compared the aerodynamic force of the new Mikasa V200W volleyball designed for Tokyo Olympics 2020, V5M5000 volleyballs designed by Molten Company, and Mikasa MVA200 volleyballs using a wind tunnel (14). Their results indicated that volleyballs' aerodynamic force varies based on their panel design. The new designed volleyball for Tokyo Olympics 2020 (Mikasa V200W ball with 18 panels) is predicted to have a relatively stable flight distance since its drag change is relatively less dependent on panel rotation. Therefore, it can be hypothesized that, during a float serve, the flight trajectory will change depending on the type of volleyball and their orientation. Besides, the new Mikasa volleyball is expected to have a longer flight distance and more stable flight compared to MVA200 and V5M5000 models, which indicates that the concave panel model on the ball surface has an influence on stabilizing the aerodynamic forces around the ball (14). Lim Pan et al. (2021) examined the use of titanium composite in sports equipment manufacture and design. Their results indicated that using pure titanium in tennis rackets improved the inertial blow force transmitted to balls through the racket (15, 16). It was shown in the research of Ming Lee et al. (2021) Therefore, it is commonly used as a superior material in the production of mountaineering and skiing equipment such as mountaineering sticks, ski poles, ice skates, etc. (15) The titanium also has a wide application in other sports equipment like fishing hooks, protective fencing masks, sailing pieces, and running shoes (15).

The prevalence of upper limb injuries was the highest, and the highest number of musculoskeletal injuries was reported. In addition, strain and sprains, in areas of the fingers, wrists and ankles, spine, toes and knees, have been reported as the most common areas of injury. (18).

In his study on students participating in student Olympiads in 2009, Nejati (2008) reported volleyball to be the riskiest sport with 35% rate of injuries (19). The study of Rettig et al. (1998) reported ball sports to be the most essential cause of hand injuries in professional players (3). The new design ball has reduced the compressive and shear forces on the finger joints; As a result, it causes more softness and less injuries. Probably the reason for the reduction of these forces is the type of material used in the inner and outer layers of the ball.

Conclusion

Based on the results of the present study, there is no significant difference in the vertical force or compressive force in the new designed ball and with Mikasa ball used in international competitions that is directly related to injuries. Therefore, it is recommended to all coaches, referees, athletes and officials in the field of volleyball: to use the new designed ball instead of the standard Mikasa ball.

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چکیده فارسی

بررسی نیروی فشاری توپ جدید والیبال طراحی شده بتا جهت پیشگیری از آسیب های ورزشی

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هدف: یکی از علت‌های اصلی آسیب های ورزشی مربوط به تجهیزات ورزشی و جنس توپ می¬باشد. لذا هدف از حاضر بررسی نیروی فشاری توپ جدید والیبال طراحی شده بتا جهت پیشگیری از آسیب های اندام فوقانی در ران والیبالیست نیز می باشد .

رسی: پژوهش حاضر از نوع کاربردی و آزمایشگاهی می باشد. به منظور بررسی نیروی فشاری توپ جدید والیبال شده بتا و مقایسه آن با سایر توپهای والیبال موجود با استفاده از دستگاه صفحه نیرو برتک انجام شد.

یری: در راستای یافته های به دست آمده از پژوهش حاضر اختلاف معنادرای بین نرمیت نمونه توپ جدید والیبال شده بتا در مقایسه با نمونه توپ های والیبال فوکس و توپ طرح قدیم بتا در اوج مولفه نیروی فشاری در راستای FZ رد(۰/۰۰۱ ≥P). ما بین توپ جدید طراحی شده و توپ استاندارد میکاسا اختلاف معنی¬داری مشاهده نشد (۰/۷۲=P).

ه ها: توپ جدید والیبال،آسیب های ورزشی، نیروهای فشاری