ANALYSIS OF MECHANICAL PROPERTIES OF DIFFERENT VOLLEYBALLS

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INTRODUCTION

Over the last two decades sports-related concussion has become increasingly recognized as a major public health issue [1]. Still, the detection of a concussion can be difficult because there is no appropriate test for an immediate diagnosis in the sporting environment [2]. Volleyball, as a noncontact-sport, was reported to have a very low concussion rate in the past [3]. An analysis of the National Collegiate Athletic Association’s Injury Surveillance System (NCAA ISS) and the High School Reporting Injuries Online (HS RIO) over a 4 year period for girls and women in the US, however, suggests a notably higher relevance of concussions in volleyball. The data show that concussions are the fourth most frequent type of injury in NCAA ISS and the third most frequent for the high school players (HS RIO) [4]. One reason for a concussive injury in volleyball is the impact situation between a ball and a head during defensive play [4].

The mechanical properties of current volleyballs were analyzed by Chiu and vonGaza. Their study already showed that there are differences in the coefficient of restitution (COR) between standardized volleyballs following the official FIVB (Fédération Internationale de Volleyball) rules [5]. The COR, as an indicator of the energy loss during a collision, can be used to influence the dissipative energy of the ball during impact and as a result of that can perhaps also influence the forces acting on the head.

The purpose of this study is to test another method for determining the COR without the need of special laboratory equipment and to analyze possible differences of the COR depending on the ball model and incident velocity.

METHODS

The test protocol was to release the volleyball from a known height onto the ground. To vary the incident velocity and compare the data with another study, three dropping heights (0.37 m, 0.75 m, 1.50 m) were chosen [6]. 28 different balls were tested, which included 10 ball models (Mikasa MVA 200, Mikasa MIP 300, Mikasa VQ2000, Mikasa MVA Lite, Molten V5M5000, Tachikara SIX.VC, Tachikara SV-5W, Baden 15-OC, Baden VX5EC, Baden V5S-00) from four manufacturers (Mikasa, Tachikara, Molten, Baden). In accordance with the official FIVB rules for the internal ball pressure (294.3 to 318.82 hPa), the balls were pressurized to 315 hPa. In order to ensure high comparability, the ball pressure was checked by a digital air pressure gauge (Tachikara) before and after the test of each individual ball. Every condition was performed until five trails were reached. The impact situation was recorded by an iPhone (model A1723) with an internal microphone which had a sampling rate of 44.1 kHz. The further data processing of the audio files was done using Matlab (R2015b; Mathworks, Natick, MA, USA) to determine the time of flight between the first and second bounce. Using the equation \( e = \frac{\sqrt{\text{ht}^2}}{2H} \) [6], the COR was calculated for the given condition by substituting in the fall height \( H \), the gravitational force \( g \) and the duration between the two ground contacts \( t_c \).

RESULTS AND DISCUSSION

The results indicate differences for the COR between the different ball models and within the ball model between the different incident velocities (Figure 1). The incident velocity seems to have a perceptible influence on the elasticity of a volleyball during an impact situation. With an increase of the incident velocity a decrease of the COR can be observed. One exception was the Baden V5S-00, which shows a slight increase of the COR from 0.37 m to 0.75 m (Figure 1). The statistical analysis of the results will provide more information about the significance of the detected differences.

![Figure 1: Relation between coefficient of restitution and dropping height for different ball models.](image)

CONCLUSIONS

Further data processing and the comparison to already existing findings will show if the methods used for this study are valid to predict the COR. More research is needed to get a better understanding of the influence factor velocity and a more appropriate knowledge about the importance of the measuring techniques.

REFERENCES