Comparison of ‘plain conditions’ and ‘close-to-reality conditions’ for evaluation of biomechanical load spectra of handball shoes

Dominik Krumma,*, Anne Gläsera, Gert Schlegela and Stephan Odenwalda

Abstract

The purpose of this paper was to compare two different testing conditions during the acquisition of biomechanical load spectra for handball shoes. Subjects performed two typical handball activities, i.e. feints and jump shots, either under ‘plain conditions’ (group I) or ‘close-to-reality conditions’ (group II). While subjects of group II performed their tasks with a handball and an obstacle in front of them that simulated a defense player, subjects of group I performed their tasks without any additional items. In total, 19 experienced amateur handball players provided written informed consent and participated. Kinematics and kinetics were recorded using an optoelectronic measurement system and a force plate. Biomechanical load spectra, which can be used to synthesize mechanical simulations for characterization of handball shoes, were evaluated from normalized vertical ground reaction forces, forefoot bending angles and temporal spatial parameters. Statistical tests such as one-way analysis of variance were conducted to test for significant differences between both groups. The results showed that the mean of maximum vertical ground reaction forces between both groups was significantly different for feints (2.2 body weight vs. 2.5 body weight) and jump shots (2.7 body weight vs. 3.1 body weight) with higher values for group II. The maximum bending angles during feints were not significantly different (17.6° vs. 17.2°), whereas the angles during jump shots were significantly different between both conditions (32.2° vs. 22.2°). In conclusion, subjects of group II showed higher effort in performing their tasks compared to subjects of group I. Therefore, the authors suggest that the acquisition of biomechanical load spectra should be performed under real conditions or at least ‘close-to-reality conditions’.

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Keywords: footwear; mechanical testing; ground reaction force; bending angle; jump shot; feint

1. Introduction

Recent advances in sport and material engineering have resulted in new equipment [1], e.g. footwear that offers greater energy return [2]. However, heretofore, the impacts of the usage of new developed material on athletes have been insufficiently examined. That indicates that there is a lack of collaboration and knowledge transfer between engineers who design the equipment and biomechanists who study the athlete-equipment interaction [1].

In the field of footwear research there have been a number of attempts to close this gap. Researchers developed test methods that in contrast to simple falling weight tests, e.g. ASTM F 1614 [3], take into consideration the athlete-equipment interaction [4]. For instance, researchers consecutively evaluated ground reaction forces of athletes during typical movements, derived load spectra from ground reaction forces, and mechanically tested footwear cushioning properties based on biomechanically derived load spectra [4–8]. In addition, Schwanitz [9] investigated the level of abstraction that can be used to mechanically simulate the athlete-equipment interaction by means of models. According to his findings, the level of abstraction within a model must be chosen with care in order to maintain the information value.

* Corresponding author. Tel.: +49-371-531-38528; fax: +49-371-531-23149.
E-mail address: dominik.krumm@mb.tu-chemnitz.de
The acquisition of ground reaction forces that represent real athlete’s behavior while performing their sport is not trivial due to limitations such as the fact that acquisitions mostly have to be performed in laboratory settings with force plates embedded in the floor and installations of video based motion analysis systems.

Since there is only limited knowledge about load spectra of handball shoes [5, 10] and because handball includes a lot of acyclic intense activities, the purpose of this study was to obtain load spectra for handball feints and jump shots as well as to examine the outcome of different acquisition conditions on load spectra. Hence, the research question reads as follows: Are there any significant differences between the two acquisition conditions, i.e. ‘plain conditions’ (group I) vs. ‘close-to-reality conditions’ (group II), to be observed in respect of (i) maximum vertical ground reaction forces for feints, (ii) maximum vertical ground reaction forces for jump shots, (iii) maximum bending angles for feints, and (iv) maximum bending angles for jump shots? These parameters were chosen since they were typically used to derive load spectra, which in turn were used to synthesize mechanical simulations for characterization of cushioning and bending stiffness properties of handball shoes [5].

2. Methods

2.1. Subjects

The criteria for subjects’ inclusion were: male, at least 18 years old, healthy and active amateur handball player with at least five years of experience. Nineteen subjects (mean ± SD: age = 28.8 ± 6.3 y, weight = 85.5 ± 12.5 kg, height = 1.83 ± 0.06 m, BMI = 25.6 ± 3.6 kg·m-2) fulfilled the inclusion criteria, provided written informed consent and participated in this study. The study was approved by a university ethical committee in accordance with the Declaration of Helsinki.

2.2. Equipment and data acquisition

The acquisition of kinematics was conducted in a human motion laboratory using an 8-camera VICON optoelectronic tracking system (Bonita 10, Oxford Metrics, Oxford, UK) with a frequency of 200 Hz. Spherical marker position data were determined by using a 3D reconstruction software (Nexus 1.8.5, Oxford Metrics, Oxford, UK). Kinetics were measured using a force plate (9287BA, Kistler Instrumente AG, Winterthur, CH) that sampled with a rate of 1000 Hz. Subjects were randomly divided into two groups that performed two typical handball activities either under ‘plain conditions’ (group I) or under ‘close-to-reality conditions’ (group II). Group I consisted of 13 (27.9 ± 5.6 y, 89.2 ± 13.1 kg, 1.84 ± 0.05 m, 26.3 ± 3.9 kg·m-2) and group II of seven subjects (30.4 ± 7.7 y, 78.8 ± 8.3 kg, 1.80 ± 0.06 m, 24.3 ± 2.5 kg·m-2). One subject participated in both groups. Each subject performed a total of eight tasks, i.e. four trials of feints and four trials of jump shots, with their own handball shoes (size UK 9.5 ± 1). While subjects of group II performed their tasks with a handball size III (Molten H3X4000, Molten Corporation, Hiroshima, Japan) and an obstacle in front of them that simulated a defense player, subjects of group I performed their tasks without any additional items. Trials were valid if the dominant foot completely hit the force plate, else trials were repeated.

2.3. Data analysis

Only kinematics and kinetics of the dominant foot were considered. Kinematics and kinetics were normalized to 101 points using Matlab (R2013b, MathWorks, Natick, MA, US). Biomechanical load spectra were evaluated from normalized vertical ground reaction forces, forefoot bending angles and temporal spatial parameters in accordance with the methods described by the working group of Odenwald [5, 7, 11]. Statistical tests to compare the ‘plain conditions’ with the ‘close-to-reality conditions’ were conducted using Matlab. In detail, Shapiro-Wilk parametric hypothesis test of composite normality was conducted to test each parameter for normal distribution. If a parameter was normal with unspecified mean and variance, then Bartlett’s test was used to test each group for homogeneity of variances. If homogeneity was proved, one-way analysis of variance was conducted to compare the means of both groups. Elsewise, if parameters were not normally distributed or groups were not homogeneous, Kruskal-Wallis test was conducted instead. For each test a p-value lower than 0.05 was considered as being significant.

3. Results

The results of the measurements showed that the mean of maximum vertical ground reaction forces between both groups was significantly different for feints as well as for jump shots with higher values for group II (Fig. 1a). These differences for feints and jump shots could also been confirmed by considering the boxplots of individual subjects ground reaction forces, in particular for the subject who participated in both groups (Fig. 2). The maximum bending angles during feints were not significantly different, whereas the angles were significantly different between both conditions during jump shots (Fig. 1b). The mean of maximum vertical ground reaction forces for feints of group II (2.5 body weight) was significantly greater than for group I (2.2 body weight). The mean of maximum vertical ground reaction forces for jump shots of group II (3.1 body weight) was significantly greater than for group I (2.7 body weight). The means of maximum bending angles for feints of group I (17.6°)
and group II (17.2°) were not significantly different. The mean of maximum bending angles for jump shots of group II (22.2°) was significantly smaller than for group I (32.2°).

The values of derived load spectra, which can be used to synthesize mechanical simulations for characterization of cushioning (Fig. 3) and bending stiffness properties (Fig. 4) of handball shoes, differ considerably between both acquisition conditions. The differences must be considered for both machine control parameters, namely ‘load/stroke’ and ‘period of time’.

Fig. 1. Bar chart indicating the mean and standard deviation of maximum vertical ground reactions (a) and bending angles (b) of two typical handball activities, i.e. feint and jump shot, separated by the acquisition conditions. Note The dark bar (n = 13) indicates the ‘plain conditions’ (group I), whereas the light bar (n = 7) indicates the ‘close-to-reality conditions’ (group II). The asterisk indicates a p-value lower than 0.05 between both groups and hence a significant difference.

Fig. 2. Boxplots of individual subjects vertical ground reaction forces for feint (a) and jump shot (b) separated by the acquisition conditions, i.e. ‘plain conditions’ (group I) and ‘close-to-reality conditions’ (group II). Note On each box the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points and outliers were plotted individually.

Fig. 3. Derived biomechanical load spectra for testing cushioning properties of handball shoes; (a) feint (forefoot); (b) jump shot (forefoot); (c) jump shot (rearfoot). Note The dark dashed line indicates the ‘plain conditions’ (group I), whereas the light solid line indicates ‘close-to-reality conditions’ (group II).

Fig. 4. Derived biomechanical load spectra for testing bending stiffness properties of handball shoes; (a) feint; (b) jump shot. Note The dark dashed line indicates the ‘plain conditions’ (group I), whereas the light solid line indicates ‘close-to-reality conditions’ (group II).
4. Discussion

The purpose of this paper was (i) to obtain load spectra for the typical handball activities feint and jump shot, and (ii) to evaluate the effects of two different acquisition conditions on the biomechanical parameters ground reaction force and forefoot bending angle. Statistical tests have shown that the maximum ground reaction forces of the ‘close-to-reality conditions’ group were significantly higher compared to the ‘plain conditions’ group. However, the bending angles showed a different behavior. During feints no statistically significant difference could be observed between both groups. During jump shots the ‘close-to-reality conditions’ group revealed decreased bending angles.

The significant difference in ground reaction forces between both groups might result from the fact, that subjects of group II showed higher efforts in performing their tasks and hence had higher exercise velocities compared to group I. Since the force-time curves depend on the velocity of running [12], the presented results were in accordance with data from literature that states that vertical and lateral impact peaks increase with increasing velocity while contact time decreases [13, 14].

Bending angles of feints between both groups were not significantly different. However, when considering the magnitude of the bending angle in relation to the period of time, there were recognizable differences between both groups. For instance, the time of maximum bending angle was reached 15 % earlier within group II compared to group I. One explanation for the fact that the maximum bending angles between ‘close-to-reality conditions’ group and ‘plain conditions’ group did not differ, might be that bending angles during feints were not velocity dependent. Further on, taking the high standard deviations between both groups into account, it could also be assumed that there is no optimal average feint movement. Instead, the results might present subjects’ very individual feint movements.

Based on the statistical analysis, it could be shown, that three out of four biomechanical parameters were significantly influenced by the data acquisition conditions. That means that not only the level of abstraction of the model used to mechanically simulate the athlete-equipment interaction has to be carefully chosen [9], but also the level of abstraction of conditions during biomechanical data acquisition. Hence, if biomechanical data will be collected for investigation of athlete-equipment interaction, it is strongly suggested to apply real or at least ‘close-to-reality’ acquisition conditions.

5. Conclusion

This paper has shown that different acquisition conditions, i.e. performing handball specific activities by means of a handball and an obstacle in front of the subjects versus performing activities without additional items, will significantly change subjects’ movement patterns as well as the resulting ground reaction forces and forefoot bending angles. The study showed that the boundary conditions of biomechanical studies, that should lead to mechanical simulations for testing sport equipment or related materials must be chosen carefully with respect of the information value. In order to investigate if ‘close-to-reality’ is always better and hence necessary, further studies with a larger number of subjects performing in both groups have to be carried out.

As a second outcome, the obtained load spectra for two typical handball activities within this study can be used to implement a mechanical simulation of the loads acting on handball shoes for obtaining repeatable and reliable information about cushioning and/or bending stiffness properties of handball shoes.

References