Increased Athletic Performance in Lighter Basketball Shoes: Shoe or Psychology Effect?

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Purpose: To determine the effect of shoe mass on performance in basketball-specific movements and how this affects changes if an athlete is aware or not of the shoe’s mass relative to other shoes. Methods: In an experimental design, 22 male participants were assigned to 2 groups. In the “aware” group, differences in the mass of the shoes were disclosed, while participants in the other group were blinded to the mass of shoes. For both groups lateral shuffle-cut and vertical-jump performances were quantified in 3 different basketball-shoe conditions (light, 352 ± 18.4 g; medium, 510 ± 17 g; heavy, 637 ± 17.7 g). A mixed ANOVA compared mean shuffle-cut and vertical-jump performances across shoes and groups. For blinded participants, perceived shoe-weight ratings were collected and compared across shoe conditions using a Friedman 2-way ANOVA. Results: In the aware group, performance in the light shoes was significantly increased by 2% (vertical jump 2%, $P < .001$; shuffle cut 2.1%, $P < .001$) compared with the heavy shoes. In the blind group, participants were unable to perceive the shoe-weight variation between conditions, and there were no significant differences in vertical-jump and shuffle-cut performance across shoes. Conclusions: Differences in performance of the aware participants were most likely due to psychological effects such as positive and negative expectancies toward the light and heavy shoes, respectively. These results underline the importance for coaches and shoe manufacturers to communicate the performance-enhancing benefits of products or other interventions to athletes to optimize their performance outcome.

Keywords: biomechanics, footwear, motion analysis, physical performance, sport psychology

The belief that a reduction in shoe mass enhances athletic performance has driven the design and marketing of lightweight shoes over the last few decades. For running, scientific evidence in support of this claim has been provided frequently,1–3 and it is assumed that a reduction in mass of 100 g decreases the metabolic cost during running by 1%.4 In contrast, data supporting the benefits of lightweight shoes in court sports like basketball are limited. During a basketball game, players may perform a maximum of 1100 discrete movements, with up to 217 high-intensity movements including jumping, shuffling, and sprinting.4,5 During each of these high-intensity discrete movements, the players must produce mechanical work to accelerate and decelerate the mass of their shoes.6 Therefore, it is intuitive to assume that light shoes have a beneficial effect on performance.

Contrary to intuition, previous studies have not found any effects of basketball-shoe weight on performance under controlled laboratory conditions. Wannop7 investigated the influence of basketball-shoe weight on performance during 10-m sprints, vertical jumps, and cutting drills. The mass of 3 tested shoes ranged from 331 to 497 g, and participants were blinded to the shoe conditions. Performances did not differ between conditions in any of the movement tasks. It was concluded that a reduction in basketball-shoe mass does not have beneficial effects on performance in basketball movements and, thus, may not be an important property to consider when selecting a shoe. This conclusion may not hold true for the real-world scenario, in which athletes are not blinded to the properties of their shoes. Athletes are purposely selecting a pair of shoes and have expectations regarding their shoes’ properties such as mass.

Roberts et al8 suggested that the performance benefits of sports equipment under playing conditions must be derived not only from physical and technical factors but also from psychological factors such as the awareness of, and the confidence in, the sports-equipment properties. The powerful effect of expectancies and beliefs about a performance-enhancing intervention on the outcome is apparent from other areas of sport-performance research and has been associated with the placebo effect.9,10 Investigating expectancy effects is essential to verify isolated intervention effects and to understand real-world performance.

Therefore, the objective of this study was to investigate how the effect of basketball-shoe weight on performance in basketball-specific movements is modified by an athlete’s awareness of the shoe weight. We hypothesized that performance would not change between shoe weights for the blinded group but that there would be performance differences across shoe conditions in the group of athletes who were aware of the shoe weights, with the lighter shoe performing better.

Methods

Participants

Twenty-two male recreational athletes (mean ± SD age 26 ± 3 y, body mass 72.1 ± 8.6 kg, height 1.77 ± 0.07 m, vigorous physical activity 8 h/wk) volunteered and gave their written informed consent to participate in this study. To be eligible for the study, participants had to be male, physically active (>3 h/wk of vigorous physical activity) and experienced in sports that require frequent jumping and shuffling (ie, >2 y of involvement in basketball, soccer, tennis, squash, or football within the last 5 y). Participants with lower-extremity injury within 6 months before the study or other
Study Design

The basketball shoe Adidas AdiZero Crazy Light 2 was used for testing. Participants wore shoe sizes US 9, 10, or 11. Custom-made fabric bags of different weights were attached to identical pairs of shoes to provide a light (mass per shoe 352 ± 18 g), medium (510 ± 17 g), or heavy (637 ± 18 g) shoe condition. The range of shoe weights corresponds to the upper and lower weight limits of currently available basketball shoes. The visually identical fabric bags were filled with plastic pellets, metal pellets, or a mixture of both to achieve similar volumes but different weights. Using Velcro strips and additional laces, the weight bags were strapped around the shoe heel to prevent any relative movement between shoe and bag (Figure 1). Preliminary pilot studies confirmed that individuals were unable to perceive weight differences.

Participants were randomly assigned to 2 groups in an experimental study design. Of the 24 participants recruited, 12 were assigned to the “aware” group, while 12 were assigned to the “blind” group. Two participants in the blind group did not complete the study, decreasing the size of the blind group to 10. There were no significant differences between groups in participant age, weight, height, shoe size, or physical activity (Table 1). From an initial questionnaire before each experiment, no systematic differences in type of sports involvement between the blind and aware groups were present. In the aware group, weight differences between shoe conditions were verbally disclosed before testing and participants were reminded of the shoe weight (ie, light, medium, or heavy) after every condition. The investigator further informed them, “We expect you to perform best in the light shoe condition and worst in the heavy shoe condition.” The oral reminders were consistent across all participants. In the blind group, participants did not receive any information about the 3 shoe conditions. The true purpose of the investigation was disclosed to all participants after testing. Neither the aware nor blinded participants were allowed to lift or touch the shoes at any time before or during the testing sessions. The investigator put the shoes on and tied them for each condition and participant.

Methodology

Each participant visited the University of Calgary’s human performance laboratory on 2 separate days. During the first visit, participants completed an initial interview, shoe fitting, and a familiarization with the movement tasks. On the second day, the actual data collection was carried out. Participants first performed a standardized warm-up protocol that included low-resistance cycling and sprints at 80% of maximum speed. Next, each participant performed 6 lateral shuffle-cut movements and six vertical countermovement jumps in each of the 3 shoe conditions. Participants were instructed to accomplish these tasks at a maximum level of effort. They were given rest periods of 1 minute between trials to avoid fatigue. After each shoe condition, subjective feedback regarding perception of the shoe weight was collected using a 5-point Likert scale, where 1 and 5 represented very light and very heavy, respectively. The order of presentation of the shoe conditions was balanced randomized.

The countermovement jump consisted of participants jumping as high as they could by reaching the highest possible wing on a Vertec Jump Tester (Power Systems, Inc, Knoxville, TN, USA) (Figure 2[a]). Participants were instructed to perform each countermovement jump using 2 legs simultaneously to ensure consistency across participants. The countermovement jump has been used extensively as a reliable method for testing vertical-jump performance.11,12 The shuffle-cut trials consisted of a lateral shuffle in 1 direction followed by a side-cut movement and a lateral shuffle in the opposite direction, where the start and finish lines were marked by the same timing gate (TC Timing System, Brower Timing Systems, Draper, UT, USA) (Figure 2[b] and Figure 3). The protocol used in this study is based on a previous protocol from our laboratory that has been shown to be reliable and valid when measuring lateral-shuffle and side-cut performance (for detailed description of the protocol, see Whitting et al13).

To evaluate shuffle-cut and vertical-jump performance, kinematic data were collected using a high-speed motion-analysis system (8 cameras; Motion Analysis Corp, Santa Rosa, CA, USA) at a sampling rate of 240 Hz. Four retroreflective markers were mounted above the right and left sides of the anterior and posterior superior iliac spine to measure 3D kinematics of the pelvis. Throughout subsequent data processing, the raw marker trajectories were reconstructed using Cortex software (Motion Analysis Corp, Santa Rosa, CA, USA), filtered using a fourth-order Butterworth low-pass filter with a cutoff frequency at 12 Hz, and imported into MATLAB (v 2013a; MathWorks, Natick, MA, USA). The trajectory of an imaginary marker representing the geometric center of the pelvis

![Figure 1 — Test shoe with attached weight bag.](image)

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was calculated as the average of the 4 pelvis-marker trajectories in all 3 dimensions. Jump performance was defined as the vertical displacement of the pelvis and calculated by subtracting the height of the pelvis center during standing from the maximum height of the pelvis center during a vertical jump. Shuffle-cut performance was quantified as the mean horizontal shuffle velocity and calculated by dividing the overall horizontal displacement of the pelvis center in the shuffle direction by the time required to complete the shuffle-cut task. The start and end of the shuffle-cut task to derive overall displacement and time were defined as the position and corresponding point in time at which the pelvis center initially reached a horizontal velocity of 0.3 m/s. Using the horizontal shuffle velocity derived from pelvis kinematics instead of shuffle time derived from pelvis kinematics or timing lights has been demonstrated to have less measurement error and variance and is thus a preferable method when quantifying shuffle-cut performance.\(^{13}\)

**Statistical Analysis**

The 3 highest-performing trials out of 6 for each shoe condition and movement were used for further analysis. All statistical tests were carried out using IBM SPSS statistics (v 20; SPSS Inc, Chicago, IL) using a significance level of \(\alpha = .05\). A mixed analysis of variance (ANOVA) with shoe weight as the repeated factor and group as the independent factor was used to examine effects of shoe weight on performance and interaction effects between groups. Bonferroni-corrected post hoc tests were carried out to determine pairwise comparisons between the shoe conditions. Shoe-weight ratings of blinded participants were analyzed using a Friedman 2-way ANOVA to determine effects of shoe mass on perceived shoe weight. To confirm that there were no effects of fatigue, the mean performance of the first 3 trials was compared with the last 3 trials for both movements in the heavy-shoe condition using paired \(t\) tests.

**Results**

A significant interaction effect between group and shoe weight was determined for both horizontal shuffle velocity (\(F_{2,128} = 6.0, P = .003\)) and vertical displacement (\(F_{2,128} = 3.7, P = .036\)). The horizontal shuffle velocity (mean \(\pm\) SD) of the aware participants in the light shoe (2.16 \(\pm\) 0.08 m/s) was significantly increased by 1.4% and 2% compared with the medium (2.13 \(\pm\) 0.09 m/s, \(P = .001\)) and heavy shoe (2.12 \(\pm\) 0.08 m/s, \(P < .001\)), respectively (Figure 4[a]). The vertical displacement (mean \(\pm\) SD) of the aware participants in the light shoe (56.7 \(\pm\) 5.5 cm) was significantly increased by 1.2% and 2.1% compared with the medium (56.1 \(\pm\) 5.9 cm, \(P = .014\)) and heavy shoe (55.5 \(\pm\) 4.4 cm, \(P < .001\)), respectively (Figure 4[b]). No significant differences in horizontal shuffle velocity (light vs heavy difference mean \(\pm\) SD, 0.00 \(\pm\) 0.05 m/s, \(P = 1.0\)) or vertical displacement (light vs heavy difference mean \(\pm\) SD, 0.3 \(\pm\) 1.4 cm, \(P = .809\)) across shoe weights were found for the blind group (Figure 4[a] and [b]). The high magnitudes of the standard deviations result from the natural between-subjects variation in jump height and shuffle velocity in the repeated-measures design. There was no significant main effect of group on horizontal shuffle velocity (\(F_{1,64} = 2, P = .158\)) or vertical displacement (\(F_{1,64} = 0.1, P = .744\)).

No significant differences were found between the perceived mean (\(\pm\) SD) weight ratings of the light (2.5 \(\pm\) 0.8), medium (2.3 \(\pm\) 0.7), and heavy shoes (2.8 \(\pm\) 0.8) among the blind-group participants (\(\chi^2[2] = 4.526, P = .104\)) (Figure 5).

There were no significant percentage differences in mean (\(\pm\) SD) performances between the first 3 trials and the last 3 trials for the lateral shuffle-cut (0% \(\pm\) 2.8%, \(P = .796\)) and the countermovement jump (0.7% \(\pm\) 2.4%, \(P = .162\)) (Figure 6[a] and [b]).
The effect of wearing basketball shoes of different weights on vertical-jump and lateral shuffle-cut performance was compared between 2 groups, 1 group that was blinded to the intervention and 1 group in which shoe-weight differences were disclosed. The results support our hypotheses that there would be no significant difference in performance among the blind group but that participants who knew the weights of the shoes would perform better in the light shoe. The finding of no performance differences across shoe weights for the blinded group must be interpreted with caution. The sample size in the blinded group was limited to 10 participants, which did not provide enough statistical power to conclude the nonexistence of a performance difference between shoes. In fact, to prove the nonexistence of a difference at a significance level of .05 and statistical power of .8, a total sample size greater than 170 participants would have been required in the blinded group. Despite the risk of a type II error, we are confident in the value and significance of this study’s findings, as they are congruent with results from previous experiments. Wannop did not find significant effects of basketball-shoe weight on jump or shuffle performance of blinded athletes. Similarly, a shoe-weight increase of 35% did not affect performance of blinded soccer players during cutting and sprinting drills. Therefore, the isolated effect of basketball-shoe weight on jumping and shuffling performance may be negligible within a shoe-weight range that is relevant with respect to the current market. The result of no difference in performance across shoe weights may be attributable to the participants’ ability to compensate for additional shoe weight in a nonfatigued state. The absence of fatigue in the current study was achieved by rest periods of 1 minute between trials and confirmed by the finding of no systematic performance decrease between the first 3 and the last 3 shuffle-cut and jumping trials. It is possible that in a nonfatigued state athletes increase the activation intensity of muscles involved in executing the movement tasks to maintain a maximum performance level. This concept of compensation for additional shoe weight implies decreased movement efficiency when performing in heavier shoes. However, it should be noted that this study investigated the performance outcome only. The concept of muscle compensation and movement efficiency requires further investigation, possibly by measuring muscle activity through electromyography and the physiological load while athletes perform shuffle and jumping tasks in different shoe weights under fatigued and nonfatigued states.

A jumping and shuffling performance difference of about 2% between the light and heavy shoes in the aware group supports the second hypothesis. To the best of our knowledge, similar study designs have not been reported in the field of sports-equipment research. However, the results can be compared with findings in other areas of sports-performance research where the effects of psychological factors, such as beliefs or expectancies regarding a performance outcome, have been demonstrated. Eleven out of 12 reviewed studies investigating expectancy effects on sports performance reported either a statistically or a clinically significant effect of expectancies toward the intervention on the performance outcome.
on the order of magnitude of 1% to 5%. Using a comprehensive balanced placebo design, McClung and Collins determined placebo and true effects of an ergogenic aid administered before a running endurance test. A group of individuals who were administered the drug and were aware of the administration were able to increase their performance significantly by 1.7%. This group is analogous to the aware group in the current study. Note that in a placebo group, the belief of receiving the drug while actually receiving a placebo treatment led to a similar significant performance enhancement of 1.5%. In contrast, a group that was administered the drug without knowledge of the study intervention did not improve in performance. This group is analogous to the blind group in the current study. It was concluded that the observed performance-enhancing effect was primarily due to positive expectancies toward the efficacy of the administered drug as opposed to the drug itself. The current study demonstrated effects of a similar order of magnitude with a performance increase of 2% in the aware group between the heavy and light shoes and no performance difference in the blind group.

Despite the lack of a placebo group in the current study, we suggest that the observed interaction effect between the aware group and blind group was due to psychological factors. Since the isolated effect of shoe weight in the blind group was not significant, we assume that differences in performance in the aware group were primarily associated with the disclosed information about the shoe-weight differences and corresponding performance expectancies. In addition, we speculate that the observed significant performance differences across shoes were due to the positive expectancies toward the light shoes and negative expectancies toward the heavy shoes. This would be consistent with results from Beedie et al., who demonstrated that while positive expectancies toward an intervention enhance performance, negative beliefs can have detrimental effects on performance. Considering the medium-weight shoe as a reference, the significant performance increase in the light shoe (1.4% and 1.2% for shuffling and jumping, respectively) was greater than the nonsignificant performance decrease in the heavy shoe (0.6% and 0.9% for jumping and shuffling, respectively). This suggests that the performance-enhancing effect of positive expectancies was larger than the detrimental effect of negative expectancies. However, further research needs to be conducted to confirm this suggestion. Future studies should incorporate a more complex design including a baseline measurement of performance and a placebo group in which participants believe they are performing in shoes of different weights while there is actually no difference in weight. This study design would allow for the individual isolated effects of expectancies toward the light and heavy shoes to be examined accurately.

 Practical Applications

This work is primarily relevant for coaches and shoe manufacturers. During exercise, athletes are not able to perceive shoe-weight differences as large as 300 g per shoe. They can only take full advantage of a light basketball shoe if they are aware of the shoe’s weight and if they are confident that the light weight of the shoe will help them perform better. The challenge for coaches and shoe manufacturers is to communicate the purported benefits and performance-enhancing properties of a shoe to the athlete to optimize the performance outcome. One solution for shoe manufacturers could be to emphasize a beneficial technology by choosing the appropriate design language and an appropriate name for the product. A good example for this solution is the test shoe used for this study, named Crazy Light 2.

The second application concerns research colleagues who are investigating performance-enhancing effects of sports equipment or other interventions. This study emphasizes the importance of a proper blinding of the research participants, as the results show that psychological factors affect performance outcomes. Future studies in the area of sport-performance research should be designed to exclude effect modification by psychological factors to isolate the intervention effect.

The practical applications of this study have to be interpreted in the context of the study’s limitations. The selected sample for this study consisted of recreational athletes. As a result, the generalization of the results with respect to elite athletes has to be made with caution, especially because of a previously proposed relationship between training status and placebo responsiveness. Finally, due to the weight bag located at the rear shoes, the weight
distribution of these shoes did not perfectly represent the weight distribution of basketball shoes available on the market. However, by adding the weight close to the rear outer sole and around the ankle joint—the main weight sources in basketball shoes—the shoe modifications were designed to mimic shoe-weight increases in a real-world scenario as closely as possible while keeping other shoe properties constant.

Conclusions

During exercise, recreational athletes are not able to differentiate between basketball shoes of the same construction and appearance but with a difference in weight within a range that represents the current market. Therefore, it was demonstrated that the isolated effect of shoe weight in blinded athletes did not yield a significant performance change in a vertical-jumping and lateral shuffle-cut task. Only after athletes were informed about the individual shoe-weight differences and told that they were expected to perform better or worse in light or heavy shoes, respectively, did performance significantly increase by about 2% in the light shoe when compared with the heavy shoe. We concluded that the positive and negative expectancies that the athletes developed toward the shoe conditions acted as effect modifiers, closely related to the placebo effect. The isolated effect of reduced basketball-shoe weight might not play a relevant role for jumping and shuffling performance. However, outside of the laboratory, the combination of a lightweight shoe and the athlete’s confidence and positive beliefs about the shoes could provide a performance benefit during a basketball game.

Acknowledgments

The authors would like to thank Adidas International for providing the testing shoes. The results of the current study do not constitute endorsement of the product by the authors or the journal. The authors declare no conflict of interest.

References