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Single-Subject Analyses Reveal Altered Performance and Muscle Activation during Vertical Jumping

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Abstract: Effects of barefoot and minimal footwear conditions on performance during jumping (i.e., jump displacement) are unclear with traditional group-level studies because of intra- and interindividual variability. We compared barefoot, minimal, and conventional athletic footwear conditions relative to countermovement vertical jump (CMVJ) performance and muscle activation using a single-subject approach. Fifteen men (1.8 ± 0.6 m; 84.5 ± 8.5 kg; 23.8 ± 2.3 y) performed three CMVJ trials in barefoot, minimal, and conventional footwear conditions while ground reaction forces (GRF) and electromyograms of eight lower extremity muscles were recorded. The Model Statistic procedure ($\alpha = 0.05$) compared conditions for CMVJ displacement, net impulse, durations of unloading, eccentric, and concentric phases, and average muscle activation amplitudes during the phases. All variables were significantly altered by footwear ($p < 0.05$) in some participants, but no participant displayed a universal response to all variables with respect to the footwear conditions. Seven of 15 participants displayed different CMVJ displacements among footwear conditions. Additional characteristics should be evaluated to reveal unique individual traits who respond similarly to specific footwear conditions. Considerations for footwear selection when aiming for acute performance enhancement during CMVJ tests should not be determined according to only group analysis results. The current single-subject approach helps to explain why a consensus on the effects of barefoot, minimal, and conventional footwear conditions during the CMVJ remains elusive.

Keywords: electromyography; ground reaction forces; jumping; performance; shoes

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1. Introduction

Barefoot and minimal footwear conditions have become popular in recent years due to claims of "natural" foot motion achieved in comparison to conventional athletic footwear [1,2]. Relative to conventional athletic footwear, minimal footwear tends to be constructed using more flexible materials that are lighter in weight and provide less arch support to replicate the barefoot environment while providing some protection [3]. In general, barefoot and minimal footwear effects have been investigated with respect to movement mechanics and overuse injury risk during running [4–8] and landing [9–12]. During running, footwear effects may be dependent on lower extremity segment orientations at ground contact [13]. However, barefoot and/or minimal footwear conditions have been shown to decrease peak impact forces [8,14] and patellofemoral joint stress [15] in comparison to conventional footwear. During landing, the lack of or reduced external cushioning when barefoot or in minimal footwear, respectively, does not increase peak impact forces during countermovement vertical jump (CMVJ) landings [9]. In addition,

the lack of external cushioning does not increase the risk of instability related traumatic events when landing from a diagonal jump [10]. This suggests that barefoot or minimal footwear conditions could be selected without overt concerns for impact-related injury risks when compared to conventional footwear.

Despite the emphasis on footwear effects relative to overuse injury potential, some view barefoot and minimal footwear conditions as potentially advantageous. This is because there may be less force attenuation by shoe materials located between the interface of the foot and ground. Initial evidence suggests that an acute change from conventional footwear (Adidas adiPURE; Adidas America, Inc., Portland, OR, USA) to barefoot and minimal footwear (Adidas Climacool Leap; Adidas America, Inc., Portland, OR, USA) can coincide with a ≈3 cm increase in CMVJ height in men [9]. This was an important result because high-level athlete rankings and predictions of career success are influenced by relatively small differences (≈5 cm) in vertical jump height [16]. According to these initial results, simple footwear interventions may have become a primary consideration among sport performance professionals seeking to realize meaningful CMVJ improvements during performance assessments without requiring lengthy technical training or strength and power development. However, such an expectation may be premature given the results of a subsequent study in which CMVJ height and peak force production was not different among barefoot, minimal (Vibram Five Fingers KSO; Vibram Corp., North Brookfield, MA, USA), and conventional (New Balance MX623; New Balance, Inc., Boston, MA, USA) footwear conditions despite altered activations of some lower extremity muscles [17]. A recent follow-up study observed no differences in jump height between the same minimal and conventional footwear in men and women despite greater peak knee joint power production when wearing conventional footwear [18]. Although outside the scope of the barefoot/minimal versus conventional footwear debate, a recent comparison between conventional and maximal cushioned footwear observed no differences in CMVJ height or other kinetic variables driving CMVJ performance, such as the eccentric rate of force development, force at amortization, and joint angular power production and work [19]. It may seem reasonable to conclude that the inconsistent jump height results among previous studies centers on the types of footwear (brand, model, etc.) compared [9,17,18]. However, such a conclusion may be inappropriate because the footwear types compared in those studies all satisfy established categorical definitions for minimal and conventional footwear [3,20].

The studies reporting no differences between or among footwear conditions [17–19] were carried out on samples estimated to provide sufficient statistical power for CMVJ performance. However, it is possible that key input parameters were inappropriate for the respective power analyses, such as using input data from a potentially underpowered sample [17], using self-selected input data use because of a lack of relevant literature [18], or inappropriateness of jump height for determining power for other variables (e.g., muscle activity). Still, the lack of clarity for footwear-driven changes during the CMVJ are likely due to large amounts of intra-individual (i.e., large trial-to-trial standard deviations) variability [21], inter-individual variability (i.e., large group standard deviations), or both, in the reported data. Intra- and inter-individual variability in those data were likely the result of unique movement strategies utilized by individuals when performing the same movement [22,23] and each individual's own muscular force production capabilities given their response to a specific footwear condition. This rationale may be obvious to athletes, practitioners, and scientists alike in light of published evidence indicating that participants' unique footwear-stimulated responses are masked during walking [24]. However, researchers, including the current author(s), have historically preferred pooling the performances of multiple individuals for group-based assessments. Thus, it is reasonable to conclude that the approach to pool participant data for group comparisons is the reason for the lack of consistent CMVJ performance results among available studies and that other approaches may be necessary. Ultimately, the group analysis approach has yet to

inspire convincing research interpretations on the effects of various footwear conditions on CMVJ performance.

In light of the information reviewed, assessments at the single-subject level [25] may be needed to reveal potentially worthwhile differences among footwear conditions. This may have value for human performance professionals aiming to quickly improve the jumping ability of an athlete through noninvasive methods, since previous group-based comparisons [9,17,18] suggest there is no "average" response to an acute change in footwear during jumping. Therefore, the purpose of this study was to determine whether barefoot and minimal footwear conditions alter CMVJ performance by way of force production and muscle activation in comparison to a conventional footwear condition, using a single-subject analysis. This analysis was utilized to determine whether interindividual variability masks potential footwear effects on CMVJ performance during group analyses and whether such masked differences can be revealed using a single-subject analysis to better understand potential effects of various footwear conditions during jumping. It was hypothesized that CMVJ performance and muscle activation would differ among footwear conditions and the direction of differences would vary across the sample.

2. Experimental Section

2.1. Subjects

This sample of participants consisted of 15 recreationally active men (1.8 ± 0.6 m; 84.5 ± 8.5 kg; 23.8 ± 2.3 y). This study was a secondary analysis of data previously published showing a lack of performance differences among barefoot, minimal, and conventional footwear during CMVJ and standing long jumps using only a group analysis approach [17]. Although the sample size was determined a priori for the original project [17], sample size is not a critical consideration for the current analysis because single-subject analyses are not sensitive to the size of the overall sample [24,26]. Participants were required to be recreationally active and experienced with jump training, as defined by regular participation in sports, exercise, and/or reactional activities involving CMVJ for at least 6 months prior to participation. Participants reported no injuries or ailments that would have affected their ability to perform maximum effort CMVJ. Participants were not required to be habitual users of any specific footwear condition. However, after completing testing they reported greater comfort and perceived performance when wearing conventional shoes versus minimal shoes and barefoot [17]. Following a description of the study procedures, informed written consent was provided to the researchers in accordance with the Institutional Review Board at the site of data collection.

2.2. Procedures

Participants visited the laboratory on two occasions, with 48–72 h separating the two visits. During the first visit, informed written consent was obtained and height, mass, shoe size, and age were recorded. During the second visit, participants completed a standardized warm up consisting of 5 min of stationary cycling at a preferred pace followed by 10 bodyweight squats, 10 jump squats, and 20 forward step walking lunges. Participants performed three CMVJ trials in the barefoot, minimal, and conventional footwear conditions, respectively. Stance width was measured and marked to ensure consistent foot placement across CMVJ trials and among footwear conditions. The footwear conditions were presented to the participants in a counterbalanced order (i.e., participant 1: barefoot, minimal, conventional; participant 2: minimal, conventional, barefoot, etc.). The minimal (KSO; Vibram Corporation, North Brookfield, MA, USA) and conventional (MX623; New Balance Athletics, Inc., Boston, MA, USA) conditions satisfied published recommendations for inclusion into these categories [3,20]. Participants were allotted a brief familiarization period (≈5 min) in each of the three footwear conditions prior to recording any CMVJ trials. Familiarization included walking within the laboratory space and performing CMVJ practice trials to feel comfortable with the footwear conditions. To promote maximum effort during each trial, a Vertec Jump Trainer (Sports Imports,

Hilliard, OH, USA) was positioned adjacent to the force platform so that the participant would jump and reach as high as possible.

Muscle activation data were obtained via surface electromyography (EMG) recorded using Myopac Jr. (RUN Technologies, Mission Viejo, CA, USA; 2000 Hz). The system had a common mode rejection of 90 dB, an input impedance of 1.0 MΩ, and gain set to 1000. The dominant limb (identified by the participants as the preferred limb to kick a ball) was marked for EMG sensor application in accordance with the SENIAM guidelines [27] for the following muscles: biceps femoris (BF), medial gastrocnemius (MG), peroneus longus (PL), semitendinosus/semimembranosus (SEM), soleus (SOL), tibialis anterior (TA), vastus lateralis (VL), and vastus medialis (VM). The marked locations were shaved and gently abraded with fine sandpaper to remove hair and debris prior to being cleansed with alcohol. The EMG electrode sensors used were 2-cm round Ag/AgCl (Ambu, Inc., Glen Burnie, MD, USA) with an interelectrode distance of 2 cm. A ground electrode was placed on the patella for signal noise reduction. Vertical ground reaction force (GRF) data were obtained synchronously with the EMG data using a three-dimensional force platform (BP600900; Advanced Mechanical Technology, Inc., Watertown, MA, USA; 2000 Hz). GRF and EMG signals were interfaced to a PC computer running Datapac 5 (RUN Technologies, Mission Viejo, CA, USA) via a 12-bit analog-to-digital converter (DAS1200Jr; Measurement Computing, Middleboro, MA, USA).

2.3. Data Processing

Raw GRF and EMG signals were exported to MATLAB (R2017a; The Mathworks, Inc., Natick, MA, USA). GRF signals were smoothed using a fourth-order, bidirectional, low-pass Butterworth digital filter with a cut-off frequency of 50 Hz, with the order and cutoff set before the two passes [28]. EMG signals were band-pass filtered using a fourth-order Butterworth digital filter with a 10–450 Hz pass. The filtered EMG signals were then full-wave rectified and smoothed using a fourth order low pass Butterworth digital filter with a 10 Hz cutoff to create a linear envelope [29]. From the smoothed GRF signal, the CMVJ was divided into unloading, eccentric, and concentric phases (Figure 1) in order to associate the data to time periods best linked to both net muscle actions and total body movement effects [30]. Accordingly, the unloading phase was defined by the start of the CMVJ, which occurred when body weight was reduced by 2.5%, and the local minimum vertical GRF. The eccentric phase was defined by the local minimum vertical GRF and the time when vertical center of mass position reached its lowest depth. The concentric phase was defined by the end of the eccentric phase and takeoff, which occurred when the vertical GRF decreased below 20 N. CMVJ time, sometimes called time to takeoff, was extracted as the time between the start of the unloading phase and take-off. In addition, the time durations of the unloading, eccentric, and concentric phases were extracted. Vertical acceleration of the center of mass was calculated from the vertical GRF data using Newton's law of acceleration ($a = \Sigma F/m$). Center of mass vertical velocity was calculated as the time-integral of the vertical acceleration data. CMVJ displacement during flight was calculated as the square of takeoff velocity (i.e., velocity at the instant of takeoff) divided by two times gravitational acceleration [31,32]. Net vertical impulse was calculated as the time-integral of the vertical GRF minus the vertical impulse due to bodyweight. From the smoothed EMG signals, the average activation amplitude was calculated for each muscle during the unloading, eccentric, and concentric phases. Average EMG magnitudes were normalized to the maximum amplitude observed throughout the respective CMVJ trial.

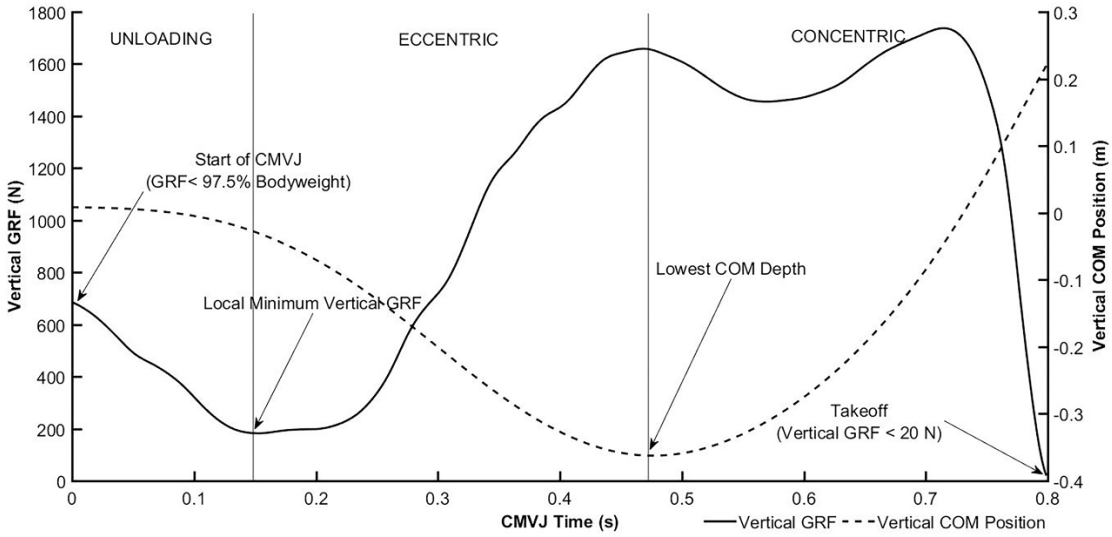

Figure 1. Exemplar representation for how the vertical force curve was deconstructed into phases for analysis. For average electromyography (EMG) amplitudes during the unloading phase (Table A3), a total of 13 differences were detected among conditions for vastus medialis (VM) and soleus (SOL), 10 for biceps femoris (BF), seven for semimembranosus (SEM) and vastus lateralis (VL), five for medial gastrocnemius (MG), and four for peroneus longus (PL) and tibialis anterior (TA) ($p < 0.05$). For average EMG amplitudes during the eccentric phase (Table A4), a total of 13 differences were detected among condition for VL and PL, 12 for SEM, 11 for TA, 10 for BF and VM, nine for SOL, and six for MG ($p < 0.05$). For average EMG amplitudes during the concentric phase (Table A5), a total of 12 differences were detected among conditions for BF, 11 for SOL, 10 for SEM, eight for VM, MG, and PL, five for TA, and four for VL ($p < 0.05$).

2.4. Statistical Analysis

Mean and standard deviation values were calculated across trials per participant for each variable of interest. Using a published MATLAB function [33], Model Statistic tests [26,34,35] were conducted to determine whether statistically significant differences existed among footwear conditions at the single-subject level. This procedure is similar to a t-test, but it accounts for the standard deviations for the comparative means and the number of observations (i.e., trials) used to determine the critical difference for the comparison between mean values [36]. As described by Bates and colleagues [26], use of three trials to determine both the comparative means and the mean difference is associated with a 1.6533 critical value for an alpha level (α) of 0.05. The possible critical values outlined by Bates and colleagues were established using a computer program that generated individual test-statistics by randomly selecting two samples of an appropriate size using normally distributed data with a mean of 0 and standard deviation of 1. Absolute differences between the sample means were computed and stored for 5000 paired samples. This was conducted and provided for sample sizes of 3–50 trials and alpha levels of 0.10, 0.05, and 0.01. The critical value was multiplied by the mean standard deviation to obtain a critical difference. If the mean difference was greater than the critical difference, the mean difference was considered statistically significant ($p < 0.05$).

3. Results

Participant-specific and group mean and standard deviation results for each condition and variable are presented in Tables A1–A5 in Appendix A. Numerous significant differences were detected across participants for all jump performance and temporal variables. For CMVJ displacement (Table A1), a total of 12 differences ($p < 0.05$) among conditions were detected. Specifically, three participants displayed greater displacements when barefoot versus both minimal and conventional, two participants displayed greater displacements when conventional versus barefoot, two displayed greater displacements when minimal versus conventional, while one displayed greater displacements when

conventional and minimal versus minimal and barefoot, respectively. As to be expected, each participant exhibiting greater CMVJ displacement in one condition versus another also showed a significantly greater net impulse in that condition ($p < 0.05$; Table A1). For jump time and the durations of the CMVJ phases (Table A2), six differences were detected among conditions for unloading time and total jump time ($p < 0.05$), while seven differences were detected for both the eccentric and concentric phase times ($p < 0.05$).

4. Discussion

The purpose of this study was to compare the effects of barefoot, minimal, and conventional footwear conditions on CMVJ performance and muscle activation using a single-subject analysis. It is important to recognize that our aim was not to determine the optimal footwear condition to be worn during CMVJ testing. Instead, our aim was to provide evidence for the use of single-subject approaches to compare different footwear types relative to biomechanics and muscle activation during jumping. The main outcome of this study was the observation that seven of the 15 participants tested (participants 2, 6, 7, 9, 10, 12, and 15; ≈47% of the sample) experienced a significant change in both CMVJ displacement and net impulse when switching among the three tested conditions. Importantly, three (participants 6, 7, and 10) of those seven participants (i.e., 20% of the total sample) displayed the greatest CMVJ displacement when barefoot, while one displayed the greatest CMVJ displacement when conventional, and the remaining participants did not exhibit dominant performances in any specific condition. Interestingly, the participants exhibiting different muscle activations among footwear conditions during the unloading phase tended to display similar differences among conditions during the eccentric and concentric phases. In addition, differences among footwear conditions were observed in every muscle across participants in each of the CMVJ phases. As such, it appears difficult to form conclusions on the ideal footwear condition to use during the CMVJ when considering the current study, previous results, or both. However, the current muscle activation results support the previous group-level conclusion that barefoot and minimal footwear conditions can alter muscle activation during the countermovement and concentric phases [17] while expanding upon those results in that such changes can occur independent of CMVJ displacement changes.

The current results highlight the value of the single-subject analysis technique as it relates to the detection of performance differences among conditions or treatments within participants [24]. Still, a general conclusion on the effects of the footwear conditions examined herein on CMVJ performance cannot be determined for the entire sample since we observed unique responses to the three footwear conditions. In addition, there does not appear to be a "typical" muscle activation response to acute changes among these footwear conditions, even in the participants displaying similar CMVJ performance among conditions (e.g., the three participants with greatest CMVJ displacement when barefoot versus minimal and conventional). Thus, muscle activation information may not be useful when seeking to identify appropriate footwear types for an individual or group of individuals. However, there may be certain characteristics not measured here (e.g., previous competitive sports participation, training, muscle architecture, etc.) that distinguish the current participants who displayed similar CMVJ performance changes when compared to the rest of the participant pool. Such potential differences may be the key to determining the true effects of these footwear conditions so that practitioners may be better able to identify optimal footwear conditions to be used during CMVJ performance assessments.

Although these results support the introductory claim that previous group-level interpretations, even when determined from the current sample [17], might not adequately represent any individual participant in the sample, the observation is not novel. For instance, a classic assessment of velocity variations during the support phase of running in elite runners showed that the average value calculated across participants did not represent any of the individuals from which the average was obtained [37]. Mean values that do not represent the individual subjects from which the mean was derived have

also been observed more recently during running and step-off landings from an elevated platform [35] and during forward step landings [38]. Thus, it should not be surprising that the footwear tested here stimulated unique responses in these participants, and the average response used during previous group analyses may be an inappropriate representation of the individual participants.

The discrepancy between previous group and the current single-subject analyses should not be interpreted such that only group or single-subject analyses be conducted when investigating potential responses to a footwear perturbation. Instead, the approach used should always be selected based on the research question, variables of interest, and expected outcomes [24]. In some cases, using both approaches simultaneously may provide the richest and most robust information. Based on the variation in responses across participants for all variables examined here, subsequent studies on the differences among barefoot, minimal, and conventional footwear conditions during CMVJ might consider using a single-subject approach in conjunction with a group-level analysis to more precisely identify potential responses or response patterns in other applicable variables. The combined approach might provide the most robust assessment of the effects different footwear conditions have on physical performance qualities, which could aid human performance professionals in identifying noninvasive methods to maximize performance during CMVJ assessments in addition to other performance tasks (e.g., running, walking, etc.).

A possible limitation to this study was the brief familiarization periods allotted per condition prior to recording CMVJ trials. Participants may have exhibited more recognizable patterns of differences among conditions had they been more familiarized to each footwear condition, though such a familiarization would have been difficult to prescribe and control. Another possible limitation was that we did not identify a specific pattern of CMVJ performance or strategy changes among the footwear conditions, as the results suggest there is no common or typical response to these footwear types. Still, it is our opinion that the current single-subject approach helps to explain why a consensus on the effects of barefoot, minimal, and conventional footwear conditions during CMVJ remains elusive.

5. Conclusions

In summary, we performed a single-subject analysis in an attempt to identify CMVJ performance, force production, and muscle activation differences among barefoot, minimal, and conventional footwear conditions. Numerous differences were revealed for each variable of interest (e.g., CMVJ displacement, net impulse, CMVJ phase durations, and lower extremity muscle activation) across participants. No explicit patterns of differences were detected for any one variable, which suggests that differences in individual morphological constraints and individual strategies from learned experiences are important contributors to the observed performance differences. Accordingly, implementation of, and recommendation for, specific footwear conditions during a CMVJ test should be determined according to the individual and not the group. These results provide evidence to help explain the lack of consistency among previous group-based studies on the effects an acute change among barefoot, minimal, and conventional footwear on CMVJ performance [9,17,18]. Previous conclusions from group level studies should be interpreted with caution since the results of those studies might not accurately represent the sample of participants from which the "average" result was obtained.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of The University of Memphis (IRB #: 2906).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. CMVJ displacement and net impulse among barefoot, minimal, and conventional footwear conditions.

Participant	CMVJ Displacement						Net Impulse					
	Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.41	0.02	0.41	0.02	0.40	0.02	242.07	4.68	246.50	5.28	240.60	6.13
2	0.39	<0.01	0.39	<0.01	0.43 ^{B}	0.03	201.83	0.47	204.35 ^{B}	0.14	211.27 ^{B,C}	5.23
3	0.37	0.04	0.36	<0.01	0.37	0.03	247.61	13.54	245.16	0.62	247.61	8.49
4	0.37	0.08	0.33	0.12	0.42	0.12	229.39	19.35	218.36	38.41	241.76	28.97
5	0.34	0.00	0.33	0.01	0.35	0.02	197.64	0.59	196.03	2.73	199.80	4.18
6	0.54 ^{M,C}	0.02	0.48	0.01	0.50 ^{C}	0.01	244.99 ^{M,C}	4.52	235.58	1.82	237.77	0.61
7	0.49 ^{M,C}	0.01	0.45	0.01	0.42	0.03	224.33 ^{M,C}	3.27	218.36	3.33	211.09	6.65
8	0.27	0.01	0.27	0.02	0.25	0.02	212.54	6.15	214.42	7.38	207.19	6.80
9	0.58	0.01	0.60 ^{B}	0.01	0.59	0.01	270.10	3.35	275.31 ^{B,M}	1.00	271.36	1.70
10	0.79 ^{M,C}	0.14	0.57	0.06	0.60	0.01	308.15 ^{M,C}	21.00	273.75	12.77	280.56	0.96
11	0.33	0.05	0.34	0.01	0.35	0.02	252.59	17.57	256.34	3.29	260.67	6.02
12	0.55	0.02	0.79 ^{B,M}	0.14	0.56	0.04	241.54	4.17	308.15 ^{B,M}	21.00	245.70	6.50
13	0.46	0.10	0.46	0.06	0.42	0.05	281.92	22.25	283.42	11.75	274.10	9.71
14	0.37	0.02	0.36	0.01	0.35	0.05	222.61	4.47	222.06	2.75	219.77	11.23
15	0.39	0.02	0.37	0.02	0.40 ^{C}	0.01	219.61	4.61	215.22	4.36	222.97 ^{C}	3.11
Group	0.44	0.13	0.43	0.13	0.43	0.10	239.79	30.04	240.87	32.72	238.15	25.80

Notes: Unit of measure for CMVJ displacement: meters (m); unit of measure for net impulse: Newton-seconds (N*s); mean: average across trials (per participant) or participants (group); SD: standard deviation across trials (per participant) or participants (group); ^{B}: significantly greater than barefoot ($p < 0.05$); ^{M}: significantly greater than minimal ($p < 0.05$); ^{C}: significantly greater than conventional ($p < 0.05$).

Table A2. Unloading, eccentric, and concentric phase and total jump time among barefoot, minimal, and conventional footwear conditions.

Participant	Unloading Time						Eccentric Time						Concentric Time						Jump Time					
	Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.25	0.1	0.26	0.05	0.27	0.05	0.29	0.11	0.27	0.02	0.22	0.06	0.21	0.00	0.23 ^{B}	0.01	0.23 ^{B}	0.01	0.75	0.03	0.75	0.04	0.73	0.08
2	0.26	0.15	0.17	0.01	0.15	0.03	0.49	0.14	0.44	0.02	0.45	0.08	0.32	0.03	0.33	0.02	0.31	0.01	1.07 ^{M,C}	0.02	0.94	0.04	0.90	0.04
3	0.71 ^{M,C}	0.05	0.28	0.24	0.22	0.03	0.10	0.00	0.30	0.18	0.41 ^{B}	0.12	0.18	0.01	0.21	0.05	0.34	0.14	1.00 ^{C}	0.06	0.79	0.06	0.97 ^{C}	0.07
4	0.45	0.37	0.55 ^{M}	0.25	0.06	0.10	0.30	0.14	0.26	0.05	0.17	0.30	0.29	0.07	0.27	0.03	0.67	0.36	1.04	0.29	1.09	0.27	0.90	0.03
5	0.20	0.02	0.20	0.04	0.18	0.02	0.24	0.04	0.27	0.04	0.25	0.02	0.28	0.01	0.27	0.00	0.29 ^{C}	0.00	0.72	0.02	0.74	0.05	0.72	0.02
6	0.27	0.09	0.25	0.09	0.31	0.15	0.28	0.02	0.29 ^{M}	0.02	0.25	0.02	0.26 ^{M}	0.00	0.26 ^{M}	0.02	0.23	0.01	0.81	0.08	0.79	0.06	0.79	0.15
7	0.17	0.04	0.15	0.02	0.14	0.03	0.35	0.05	0.36	0.05	0.41	0.07	0.29	0.02	0.30	0.04	0.31	0.03	0.81	0.04	0.81	0.10	0.85	0.07
8	0.15	0.03	0.13	0.03	0.15	0.05	0.29	0.03	0.27	0.02	0.29	0.04	0.30 ^{M}	0.01	0.29	0.02	0.28	0.01	0.74	0.05	0.68	0.02	0.72	0.06
9	0.16	0.07	0.20	0.01	0.15	0.06	0.44	0.07	0.40	0.01	0.55 ^{C}	0.09	0.27	0.01	0.27	0.01	0.26	0.01	0.87	0.04	0.86	0.01	0.96 ^{B,C}	0.04
10	0.12	0.21	0.93	0.70	0.46 ^{B}	0.10	0.11	0.18	0.37 ^{B}	0.03	0.33 ^{B}	0.02	1.01	0.72	0.31 ^{M}	0.01	0.28	0.01	1.24	0.41	1.61	0.67	1.06	0.11
11	0.20	0.13	0.28 ^{M}	0.03	0.13	0.01	0.49	0.14	0.35	0.03	0.54 ^{C}	0.03	0.32	0.03	0.33	0.00	0.33	0.01	1.01	0.06	0.96	0.02	1.00	0.03
12	0.26	0.14	0.12	0.21	0.19	0.02	0.31	0.01	0.11	0.18	0.33 ^{C}	0.02	0.32	0.01	1.01	0.72	0.30	0.02	0.89	0.13	1.24	0.41	0.82	0.03
13	0.18	0.05	0.12	0.02	0.13	0.01	0.27	0.04	0.27	0.02	0.28	0.03	0.30	0.04	0.30	0.04	0.29	0.03	0.75 ^{M}	0.03	0.70	0.04	0.70	0.00
14	0.13	0.04	0.11	0.00	0.16 ^{C}	0.03	0.40	0.20	0.31	0.01	0.43	0.18	0.28	0.01	0.29	0.00	0.28	0.03	0.81	0.24	0.72	0.00	0.88	0.16
15	0.29	0.01	0.32	0.06	0.25	0.05	0.51	0.02	0.51	0.02	0.48	0.05	0.29	0.02	0.31	0.03	0.32	0.04	1.09	0.03	1.13	0.05	1.05	0.13
Group	0.25	0.15	0.27	0.22	0.20	0.10	0.32	0.13	0.32	0.09	0.36	0.12	0.33	0.19	0.33	0.19	0.31	0.10	0.91	0.16	0.92	0.25	0.87	0.12

Notes: Unit of measure: seconds (s); mean: average across trials (per participant) or participants (group); SD: standard deviation across trials (per participant) or participants (group); ^{B}: significantly greater than barefoot ($p < 0.05$); ^{M}: significantly greater than minimal ($p < 0.05$); ^{C}: significantly greater than conventional ($p < 0.05$).

Table A3. Average EMG amplitudes during the unloading phase among barefoot, minimal, and conventional footwear conditions.

Participant	Biceps Femoris (BF)						Semitendinosus (SEM)						Vastus Lateralis (VL)						Vastus Medialis (VM)					
	Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	1.5	0.7	1.2	0.7	1.3	0.3	1.9	1.4	2.0	0.4	2.7	1.4	1.6	0.3	1.4	0.2	1.8	0.5	1.0	0.5	1.1	0.7	1.9	1.0
2	11.3 ^{M,C}	0.1	10.1	0.4	3.2	1.4	0.9	0.5	1.2	0.1	0.9	0.2	0.8	0.7	1.3	0.1	0.8	0.5	2.2	1.3	1.3	0.0	1.9	0.1
3	7.3	4.6	4.3	2.4	3.2	1.7	2.0 ^{M}	0.4	1.6 ^{M}	0.5	0.9	0.2	2.6 ^{M,C}	0.8	0.8	0.6	1.5	0.3	3.0 ^{B,M}	0.4	0.7 ^{M}	0.3	2.0	0.3
4	11.3 ^{M,C}	2.6	5.9	3.8	3.6	0.3	1.1	0.7	2.0 ^{B,M}	0.3	0.5	0.5	2.4	0.8	2.3	0.7	2.0	0.0	1.4 ^{M}	0.7	1.4 ^{M}	0.1	0.5	0.1
5	5.7 ^{C}	2.3	1.8	1.0	3.5	2.8	2.5 ^{M}	0.3	3.3	1.8	1.9	0.2	1.2	0.2	1.7	0.6	0.9	0.3	1.9	0.2	2.8	1.0	2.3	0.6
6	3.0	1.4	6.2	4.9	3.2	2.0	2.8	0.5	3.2	0.3	2.3	0.7	2.5	0.7	1.8	1.0	1.4	0.9	0.9	0.0	1.1	1.1	1.0	0.5
7	3.4	2.3	2.9	1.7	3.2	0.8	1.4	0.3	1.1	0.3	1.0	0.3	1.9	0.2	2.2	0.3	2.3 ^{B}	0.2	3.1	1.0	2.9	0.9	3.2	0.2
8	4.3	1.5	5.2	0.8	4.7	0.8	2.5	1.4	3.1	0.4	2.5	0.9	1.4	0.4	1.0	0.2	1.1	0.3	2.1 ^{M,C}	0.6	1.1	0.3	1.1	0.4
9	2.6	0.9	4.9 ^{B}	1.3	4.4	3.6	1.1	0.1	1.0	0.3	0.8	0.6	1.0	0.2	1.3	0.2	1.0	0.3	1.7 ^{C}	0.4	1.1	0.0	1.6 ^{C}	0.4
10	2.4 ^{C}	1.2	0.1	0.1	1.2 ^{C}	0.2	1.0	0.4	1.1	0.3	1.0	0.2	1.5	1.1	1.3	0.6	1.5	0.3	0.5	0.2	0.7	0.4	0.6	0.1
11	2.6	0.9	3.1	0.4	3.1	0.4	1.8	0.8	1.5 ^{M}	0.1	1.0	0.4	1.8	0.3	1.5	0.1	1.4	0.3	1.2	0.3	1.5	0.6	0.8	0.2
12	0.3	0.3	2.4 ^{B,M}	1.2	0.2	0.1	0.5	0.3	1.0	0.4	0.9	0.4	1.1	0.7	1.5	1.1	0.6	0.2	1.1 ^{M,C}	0.2	0.5	0.2	0.6	0.1
13	0.5	0.0	0.4	0.2	0.5	0.2	0.8	0.1	0.7	0.2	0.7	0.3	0.8	0.3	0.5	0.2	0.5	0.1	0.9	0.2	0.8	0.1	0.8	0.1
14	1.1	0.5	2.4	2.0	0.8	0.4	2.7	0.7	5.2 ^{B}	1.4	4.7	3.7	1.8 ^{M}	0.4	3.1 ^{B,M}	0.4	1.2	0.2	1.7	0.8	3.3 ^{B,M}	0.6	2.0	1.0
15	0.6	0.1	0.6	0.0	0.6	0.0	0.9	0.6	0.5	0.2	0.6	0.3	2.4 ^{M}	0.1	1.8	0.7	1.6	0.4	0.5	0.1	0.5	0.2	0.5	0.3
Group	3.9	3.6	3.4	2.7	2.4	1.5	1.6	0.8	1.9	1.3	1.5	1.1	1.6	0.6	1.6	0.7	1.3	0.5	1.6	0.8	1.4	0.9	1.4	0.8

Participant	Medial Gastrocnemius (MG)						Soleus (SOL)						Peroneus Longus (PL)						Tibialis Anterior (TA)					
	Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.7	0.3	0.8	0.2	1.2	0.4	1.3	0.7	1.8	0.8	2.5	1.2	1.7	0.2	1.7	0.5	2.4	0.9	7.4	4.5	7.2	2.2	9.7	6.2
2	0.4	0.2	1.0	0.6	0.9 ^{B}	0.2	0.5	0.0	0.6 ^{B}	0.0	0.6 ^{B}	0.1	1.4	0.5	1.6	0.5	1.7	0.3	4.4	1.3	3.5	1.9	5.4	1.4
3	2.5 ^{M}	1.3	1.0	1.0	0.2	0.0	2.0 ^{M}	0.4	2.2 ^{M}	0.8	0.8	0.6	8.7 ^{M,C}	1.5	8.0	1.8	3.1	2.1	11.3	1.4	10.8	2.0	12.4	2.5
4	0.3	0.0	0.3	0.0	0.3	0.0	0.7	0.4	0.7 ^{M}	0.1	0.5	0.1	1.7	1.9	2.3 ^{M}	1.3	0.5	0.6	2.2	1.8	3.5 ^{M}	1.2	0.6	0.7
5	2.6 ^{C}	1.0	1.0	0.4	1.5	0.3	3.0	1.1	2.8	1.0	1.9	0.8	11.9	3.6	16.9	4.5	12.5	2.8	8.7	3.0	17.0 ^{B}	5.9	12.4	2.9
6	0.6	0.1	1.1	0.6	1.1	1.0	0.6	0.3	0.8	0.4	0.7	0.1	1.3	0.5	1.5	0.5	1.2	0.7	6.3	2.1	6.2	3.3	5.7	1.9
7	0.7	0.4	0.7	0.3	1.0	0.4	1.5 ^{C}	0.4	1.3	0.6	2.0 ^{C}	0.1	1.3	0.3	1.4	0.4	1.5	0.2	3.7	0.3	4.9	2.9	2.4	2.3
8	0.9	0.3	1.4	0.3	1.7 ^{B}	0.2	1.7	0.6	2.0	0.4	1.7	0.4	5.2	1.4	4.9	1.2	3.9	0.5	8.3	2.9	10.2 ^{M}	1.7	6.7	1.8
9	0.1	0.0	0.2	0.0	0.2 ^{B}	0.1	0.4	0.1	0.3	0.0	0.4	0.1	1.1	0.6	1.6	1.1	0.6	0.3	1.7	0.8	2.8 ^{M}	0.7	1.5	0.5
10	1.4	2.0	2.0	0.5	2.9	1.8	1.2	1.6	3.0	1.6	1.5	0.4	1.1	0.8	2.7	2.9	1.1	0.3	1.9	1.5	2.4	1.6	1.3	1.0
11	0.3	0.1	0.3	0.1	0.3	0.1	1.4	0.1	2.0 ^{B}	0.4	1.6	0.3	0.9	0.1	1.0	0.2	0.8	0.2	3.2	3.0	2.3	0.2	2.3	1.1
12	0.2	0.0	1.4	2.0	0.3	0.2	0.6	0.3	1.2	1.6	0.5	0.3	1.6	0.2	1.1	0.8	1.5	1.2	1.7	0.9	1.9	1.5	2.1	2.3
13	0.2	0.1	0.2	0.1	0.3	0.1	3.9	1.3	5.2	1.1	6.6 ^{B}	1.8	3.0	0.4	2.9	0.6	3.1	0.4	13.7	4.8	13.0	3.9	13.9	3.0
14	0.5	0.1	0.4	0.1	0.5	0.2	1.1 ^{B}	0.1	0.8	0.2	0.9	0.3	7.0	5.0	7.8	1.7	4.3	1.9	7.9	6.5	9.2	2.7	4.6	3.4
15	0.2	0.1	0.8	0.6	0.5	0.3	0.5	0.1	0.4	0.3	0.4	0.2	0.9	0.3	1.1 ^{M}	0.3	0.6	0.4	3.9	2.5	1.7	0.5	1.9	1.5
Group	0.8	0.8	0.8	0.5	0.9	0.7	1.3	1.0	1.7	1.3	1.5	1.6	3.2	3.4	3.8	4.3	2.6	3.0	5.8	3.7	6.5	4.7	5.5	4.5

Notes: Unit of measure: percentage (%) of maximum amplitude during the CMVJ; mean: average across trials (per participant) or participants (group); SD: standard deviation across trials (per participant) or participants (group); ^{B}: significantly greater than barefoot ($p < 0.05$); ^{M}: significantly greater than minimal ($p < 0.05$); ^{C}: significantly greater than conventional ($p < 0.05$).

Table A4. Average EMG amplitudes during the eccentric phase among barefoot, minimal, and conventional footwear conditions.

Participant	Biceps Femoris (BF)						Semitendinosus (SEM)						Vastus Lateralis (VL)						Vastus Medialis (VM)					
	Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	2.1	1.1	1.4	1.0	1.7	0.6	12.4	4.9	14.9	1.3	15.9	2.4	8.7	1.0	10.0	1.4	9.2	2.0	13.5	3.4	10.6	1.7	14.9 ^{C}	2.3
2	12.5 ^{M}	1.8	11.1	1.1	4.4	1.8	5.0	1.3	5.5	0.9	6.9	1.8	1.1	0.9	2.4 ^{B,M}	0.4	1.8	0.8	8.2 ^{M,C}	3.9	6.7	1.0	6.8	0.0
3	9.7	5.7	5.0	2.4	3.4	1.7	14.0 ^{M,C}	1.3	4.8	2.1	3.4	2.6	11.5 ^{M}	1.9	7.2	4.9	4.0	0.9	10.8	3.3	3.9	1.0	3.9	1.0
4	12.4 ^{M,C}	3.2	5.8	4.1	5.1	0.0	4.4	0.7	10.0 ^{B,M}	0.9	6.0 ^{B}	0.0	6.5	0.7	7.1	2.3	8.9 ^{B}	0.0	8.3	3.1	9.9 ^{M}	1.2	6.3	0.0
5	8.9	4.7	3.4	1.4	4.8	3.9	15.4	2.0	10.9	3.3	13.3	2.9	14.8 ^{M,C}	3.4	9.0	3.1	9.3	3.0	17.1 ^{C}	1.4	12.2	0.9	16.5 ^{C}	1.1
6	5.7	1.2	9.3	4.5	6.1	4.4	10.1	4.2	8.1	2.6	7.1	1.5	13.8	2.6	11.1	1.4	12.4	3.2	11.1	2.0	14.5	3.1	16.4	4.5
7	3.8	2.4	3.5	2.5	3.2	0.9	7.9 ^{M}	1.4	6.8	1.3	5.5	1.6	8.4	2.6	8.9	1.4	9.1	1.8	10.6	4.4	8.7	3.9	8.1	0.6
8	5.3	2.2	7.3	2.1	6.0	0.8	9.2 ^{M}	2.1	10.4 ^{M}	3.4	3.1	0.3	9.6	2.3	9.5	1.8	9.1	3.9	10.3	3.3	12.4	5.2	7.2	1.7
9	2.9	0.9	6.0 ^{B}	1.2	4.6	3.5	6.5	1.2	7.8 ^{M}	1.3	4.5	1.6	6.3	1.5	8.5 ^{B,M}	0.6	6.2	1.0	7.7	2.9	7.7	1.9	6.9	1.0
10	3.3 ^{M,C}	0.0	0.3	0.2	1.5 ^{C}	0.2	11.7	0.0	11.8	2.8	10.9	1.9	8.9	0.0	7.5	1.8	10.6	2.4	9.3	0.0	8.9	3.3	7.6	1.7
11	2.8	1.0	3.5	0.6	3.5	0.7	11.8	5.9	11.0 ^{M}	1.7	7.6	1.3	8.1	2.3	7.6	0.4	6.4	2.4	7.9	3.2	10.0 ^{M}	1.1	5.9	0.9
12	2.1	0.4	3.3 ^{B,M}	0.0	2.8 ^{B}	0.3	5.1	0.2	11.7 ^{B,M}	0.0	5.8	1.6	6.9	1.5	8.9 ^{B}	0.0	6.9	2.1	11.7 ^{M}	2.5	9.3 ^{M}	0.0	7.3	0.4
13	2.8	1.3	2.5	1.1	4.1	1.3	4.4	2.0	5.3	1.2	6.7	0.6	3.8	0.6	4.4	1.8	4.6 ^{B}	0.1	4.5	1.6	5.9	3.9	6.2	0.5
14	7.2	4.0	5.6	2.0	4.2	1.1	5.8	1.6	5.2	1.1	6.0	0.6	10.7	4.4	13.1 ^{M}	1.9	7.7	2.1	9.7	4.5	10.5	2.8	9.3	3.1
15	2.6	0.7	2.3	0.3	2.4	0.5	5.3	1.8	3.9	1.7	4.8	1.1	10.9 ^{M,C}	0.9	8.1	1.5	6.9	1.8	8.3 ^{M,C}	0.8	7.0	0.8	7.1	0.1
Group	5.6	3.7	4.7	2.9	3.8	1.4	8.6	3.7	8.5	3.2	7.2	3.6	8.7	3.5	8.2	2.5	7.6	2.7	9.9	2.9	9.2	2.7	8.7	3.9

Participant	Medial Gastrocnemius (MG)						Soleus (SOL)						Peroneus Longus (PL)						Tibialis Anterior (TA)					
	Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	7.3	2.9	6.7	1.5	10.0	4.8	8.9	5.2	11.4	3.8	9.6	5.8	12.3 ^{M,C}	5.1	11.5 ^{M}	2.6	9.0	5.3	6.8	3.5	9.1	1.8	11.2	2.6
2	2.0	0.5	2.2	0.8	2.7	0.2	1.8	1.3	1.5	0.1	3.4	0.1	2.4	0.6	3.3	0.2	3.8	0.3	10.0	1.8	8.2	0.9	10.3	0.2
3	24.1 ^{M,C}	5.9	9.1	7.5	2.5	3.1	16.4	2.8	10.1	9.7	3.2	2.4	9.0 ^{M}	5.3	6.1 ^{M}	2.2	2.6	0.8	2.5	1.1	7.6	5.2	9.8 ^{B}	2.7
4	8.4	4.1	9.7 ^{M}	1.6	7.9	0.0	7.6	4.5	9.4 ^{M}	0.3	6.0	0.0	10.3 ^{M}	1.4	12.9 ^{B,M}	0.9	6.9	0.0	12.1 ^{M}	3.0	10.5 ^{M}	0.1	8.3	0.0
5	3.4 ^{C}	0.4	2.3	0.6	2.7	0.7	6.6	0.7	5.8	1.0	6.2	2.3	11.0	2.6	13.9	4.1	13.0	1.1	6.4	1.6	11.7 ^{B}	2.3	11.0 ^{B}	1.1
6	8.0	1.3	5.9	3.5	8.0	0.8	8.0 ^{M}	2.0	5.7	1.5	11.7 ^{C}	1.7	5.3	1.3	6.7	2.1	9.5 ^{B}	2.2	10.6 ^{M}	1.0	9.0	3.4	7.0	1.5
7	4.3	2.4	4.3	1.5	3.0	0.6	5.9 ^{M}	0.9	6.4	3.0	4.2	0.9	5.2	1.7	6.0	1.6	4.4	1.2	14.4 ^{M}	3.6	10.5	1.9	7.8	2.0
8	4.0	1.3	4.8	1.3	3.7	0.4	6.5	1.5	9.7	4.1	7.5	2.1	12.5	1.2	12.3	0.8	10.9	2.6	10.7	2.8	13.3 ^{M}	1.9	10.4	1.3
9	2.7	0.4	2.0	0.5	2.3	0.8	3.3	0.6	1.9 ^{B}	0.5	2.5	0.8	3.1	0.7	4.2	1.6	3.1	0.5	5.6	2.0	8.3 ^{B}	0.9	8.0	2.4
10	4.4	0.0	4.2	0.6	3.7	2.6	3.8	0.0	6.7	3.0	6.5 ^{B}	1.8	5.8	0.0	7.1	2.8	7.2	2.3	11.7 ^{C}	0.0	10.0	0.1	9.6	2.4
11	1.5	1.1	0.9	0.3	0.9	0.2	3.4	0.2	4.0	0.9	4.1 ^{B}	0.5	3.7	1.4	3.4	0.8	2.6	1.2	7.8	2.0	8.3	1.1	9.2	3.6
12	2.1	0.5	4.4 ^{B,M}	0.0	2.8	0.4	5.9	2.1	3.8	0.0	6.2 ^{C}	1.4	6.8 ^{C}	0.7	5.8	0.0	11.3 ^{B,C}	1.1	5.8	3.3	11.7 ^{B}	0.0	10.8	3.9
13	1.9	1.6	0.9	1.1	1.7	1.6	4.0	0.3	4.5	1.1	5.2	0.9	4.1	1.5	4.4	0.6	3.9	1.5	11.3	1.9	12.0	1.0	13.2	1.3
14	8.1	3.9	5.6	2.4	6.8	0.2	8.8	3.4	6.3	2.0	8.8	1.6	10.6	1.3	12.8 ^{B}	1.1	10.6	1.8	13.1	5.7	11.5	2.8	10.9	2.4
15	1.1	0.4	0.7	0.2	0.6	0.4	4.0 ^{M}	0.6	3.4	1.3	3.3	2.5	6.2	1.9	7.8	1.8	5.3	1.4	8.8	2.8	9.5	1.4	10.2	1.3
Group	5.6	5.7	4.2	2.8	3.9	2.8	6.3	3.5	6.0	3.0	5.9	2.6	7.2	3.4	7.9	3.8	6.9	3.5	9.2	3.3	10.1	1.7	9.8	1.6

Notes: Unit of measure: percentage (%) of maximum amplitude during the CMVJ; mean: average across trials (per participant) or participants (group); SD: standard deviation across trials (per participant) or participants (group); ^{B}: significantly greater than barefoot ($p < 0.05$); ^{M}: significantly greater than minimal ($p < 0.05$); ^{C}: significantly greater than conventional ($p < 0.05$).

Table A5. Average EMG amplitudes during the concentric phase among barefoot, minimal, and conventional footwear conditions.

Participant	Biceps Femoris (BF)						Semitendinosus (SEM)						Vastus Lateralis (VL)						Vastus Medialis (VM)					
	Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	3.4	0.2	3.6	1.7	3.7	1.4	11.1	3.8	14.1	2.1	18.1 ^{B}	4.6	18.4	4.6	21.6 ^{M}	1.4	13.4	3.4	16.3	2.8	19.4	3.7	17.0	4.8
2	16.0 ^{M}	2.6	14.1 ^{M}	1.9	5.0	2.2	10.4	0.1	15.9 ^{B}	0.8	16.4 ^{B,C}	3.0	2.2	1.7	3.8	0.6	2.6	1.6	19.3	2.6	16.1	4.3	17.1	0.9
3	15.1 ^{M,C}	2.3	7.7	2.7	5.0	1.5	8.7 ^{C}	0.1	6.1	1.2	10.0 ^{C}	1.9	21.1	3.2	17.2	5.9	18.1	4.7	17.5	3.1	12.1	4.9	15.2	5.4
4	14.0 ^{M,C}	3.3	6.8	4.3	8.2	2.0	7.0	2.2	11.1 ^{B,M}	0.5	7.5	0.4	19.5	1.3	20.3	2.2	15.6	10.7	18.4	4.9	18.5 ^{M}	0.0	10.5	6.6
5	8.4 ^{C}	4.0	2.8	0.9	4.6	3.2	12.2	1.3	10.2	2.5	11.2	3.6	15.2 ^{C}	0.7	12.1	1.4	12.6	2.3	15.3	2.1	14.1	1.5	16.3 ^{C}	0.8
6	5.4	2.2	9.3	7.6	4.2	2.0	10.9	1.0	14.1	3.9	11.2	2.7	18.3	2.9	17.6	4.5	17.5	2.6	15.3	0.6	20.5	3.0	18.9	7.8
7	5.0	2.5	4.2	3.0	3.9	0.8	13.6	2.9	14.0	1.0	11.7	5.0	16.9	4.0	15.6	1.3	18.3	3.4	15.7	5.6	14.9	4.5	14.8	1.2
8	5.1	2.0	7.1	1.6	5.4	0.7	14.4 ^{M}	3.1	12.6 ^{M}	0.6	6.0	1.1	19.9	0.7	20.3	0.6	19.1	4.6	18.8 ^{M}	2.0	21.9 ^{M}	6.0	14.6	1.9
9	3.5	1.0	7.1 ^{B}	1.9	5.9	4.4	12.0	3.1	11.7	2.1	9.6	2.1	14.9	3.0	17.5	0.3	16.4	3.1	15.4	4.1	13.5	2.1	14.7	2.0
10	3.7 ^{M,C}	0.9	1.1	0.7	1.9	0.3	12.6	7.6	19.8	3.3	21.7	2.6	12.1	7.5	16.7	3.2	18.1	0.7	8.7	4.9	16.6 ^{B}	4.3	14.2	1.6
11	2.9	1.0	3.6	0.8	4.3 ^{B}	0.7	21.4	2.6	18.6	1.6	20.3	2.1	20.0	2.1	20.5	1.9	20.0	5.4	19.4	0.5	20.1	2.4	18.8	1.0
12	4.9	1.7	3.7	0.9	4.6	0.8	4.8	0.8	12.6	7.6	6.1	1.6	14.0	4.1	12.1	7.5	12.3	4.1	17.7 ^{C}	5.3	8.7	4.9	14.1	1.3
13	10.8 ^{M,C}	1.8	6.3	0.1	6.8	1.3	10.8	2.0	8.8	0.9	9.6	1.9	15.4	0.1	15.2	2.0	15.4	5.0	19.7	4.2	17.1	7.1	17.4	3.6
14	11.4	2.1	13.7	6.0	10.2	3.7	7.2	1.8	8.3	1.9	10.1	2.5	17.1	3.6	21.6 ^{M}	2.2	15.3	2.0	13.7	1.4	19.1 ^{B}	3.3	19.1 ^{B}	2.8
15	9.5	0.8	9.6	2.1	10.2	1.2	3.6	1.5	4.3	1.5	5.0	0.9	22.4 ^{M}	2.5	16.6	4.3	15.9	2.7	16.2	2.5	16.2	3.6	15.9	0.5
Group	7.9	4.6	6.7	3.8	5.6	2.4	10.7	4.3	12.1	4.3	11.6	5.2	16.5	4.9	16.6	4.7	15.4	4.2	16.5	2.8	16.6	3.5	15.9	2.3

Participant	Medial Gastrocnemius (MG)						Soleus (SOL)						Peroneus Longus (PL)						Tibialis Anterior (TA)					
	Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal		Barefoot		Conventional		Minimal	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	13.3	2.8	16.7	1.0	19.9 ^{B,C}	1.9	14.2	3.6	15.0	3.6	14.9	4.9	16.1	0.5	18.9	4.4	17.9	4.2	1.8	0.3	1.9	0.2	3.0 ^{B,C}	0.2
2	15.9 ^{M}	1.6	16.3 ^{M}	0.0	9.4	0.1	17.1 ^{C}	0.8	14.0	0.4	19.1 ^{B,C}	0.4	15.8	0.1	18.8 ^{B,M}	1.9	17.7	3.0	9.0	2.7	7.3	0.9	9.0	0.8
3	16.8 ^{C}	3.2	12.0	2.5	13.9	1.8	16.8	2.6	17.0	4.8	14.3	10.2	20.1 ^{M}	2.4	15.6 ^{M}	4.0	7.5	3.8	1.4	0.3	1.3	0.2	2.7	1.7
4	15.8	1.4	13.3	2.7	9.8	5.9	14.5 ^{M}	1.7	15.9 ^{M}	0.0	8.7	2.0	20.3 ^{M}	0.9	17.7 ^{M}	3.2	11.9	3.9	6.6 ^{M}	1.0	5.7 ^{M}	1.0	4.5	0.5
5	12.9	3.6	14.3	3.5	14.2	1.4	10.1	4.2	10.8	2.0	12.0	5.5	13.9	1.5	11.9	1.9	14.8	1.7	5.2	0.7	5.9	1.2	6.8 ^{B}	1.1
6	14.9	1.5	15.6	1.3	12.8	2.9	17.2	1.0	15.2	3.7	19.7	2.3	17.4	1.6	17.6	1.9	18.6	3.9	4.6	2.4	3.4	2.4	4.8	1.4
7	16.6	7.1	13.6	2.4	16.5	1.9	16.8	2.4	15.8	3.0	16.1	1.6	17.6	2.4	16.7	1.1	16.1	4.6	4.7	0.1	5.9	1.5	4.6	1.3
8	14.5	0.7	19.0	4.1	14.9	1.3	15.3	1.2	17.7	1.9	14.6	1.9	17.9 ^{M}	2.5	14.7	3.9	14.2	1.3	5.3	2.3	5.4	0.8	5.1	1.0
9	14.7	4.6	18.8	2.6	16.0	4.5	17.4	3.4	18.0	2.1	20.1	2.1	15.9	1.6	19.3 ^{M}	3.1	14.3	1.6	6.8	0.9	7.2	1.5	7.5	2.6
10	9.1	5.5	15.3	2.7	14.7	4.5	9.5	5.2	17.9 ^{B,M}	0.9	14.6	0.6	9.1	5.9	16.0	3.4	16.7	2.8	3.5	1.3	3.2	1.7	2.1	0.6
11	15.7	2.4	15.0	2.1	17.9	1.3	16.1	0.5	18.7 ^{B}	1.8	20.0 ^{B}	0.4	19.7	1.8	18.2	1.8	18.5	5.1	2.6	0.9	2.9	1.0	3.3	0.3
12	14.2	4.0	9.1	5.5	15.8	5.3	17.0	5.1	9.5	5.2	16.4 ^{C}	1.2	10.7	2.4	9.1	5.9	13.5	0.8	3.4	1.6	3.5	1.3	4.6	0.3
13	15.3 ^{C}	1.7	11.0	1.9	13.6	2.9	15.9	1.0	18.0	4.5	22.9 ^{B}	0.5	15.0	1.7	15.5	0.5	16.0	4.0	4.0	2.1	5.5	1.3	4.0	1.4
14	13.4	1.4	17.4	3.5	15.5 ^{B}	0.8	13.0	1.5	15.0	3.6	15.8	2.6	4.9	1.3	5.8	0.9	6.1	2.1	4.4	1.0	4.8	1.3	3.7	0.3
15	13.1 ^{M}	1.6	10.4	2.5	9.5	0.4	13.9	3.2	10.3	5.2	13.9	2.8	18.9	1.0	17.9	1.5	16.3	4.6	4.3	1.8	5.4	1.4	3.9	2.2
Group	14.4	1.9	14.5	3.0	14.3	3.0	15.0	2.5	15.3	3.0	16.2	3.6	15.6	4.4	15.6	3.9	14.7	3.7	4.5	2.0	4.6	1.8	4.6	1.9

Notes: Unit of measure: percentage (%) of maximum amplitude during the CMVJ; mean: average across trials (per participant) or participants (group); SD: standard deviation across trials (per participant) or participants (group); ^{B}: significantly greater than barefoot ($p < 0.05$); ^{M}: significantly greater than minimal ($p < 0.05$); ^{C}: significantly greater than conventional ($p < 0.05$).

References

1. Rixe, J.A.; Gallo, R.A.; Silvis, M.L. The Barefoot Debate: Can Minimalist Shoes Reduce Running-Related Injuries? *Curr. Sports Med. Rep.* **2012**, *11*, 160–165. [CrossRef]
2. Rothschild, C. Running Barefoot or in Minimalist Shoes: Evidence or Conjecture? *Strength Cond. J.* **2012**, *34*, 8–17. [CrossRef]
3. Bowles, C.; Ambegaonkar, J.P.; Cortes, N.; Caswell, S.; Mokha, M. Footwear for Distance Runners: The Minimalism Trend. *Int. J. Athl. Ther. Train.* **2012**, *17*, 14–18. [CrossRef]
4. Braunstein, B.; Arampatzis, A.; Eysel, P.; Brüggemann, G.-P. Footwear affects the gearing at the ankle and knee joints during running. *J. Biomech.* **2010**, *43*, 2120–2125. [CrossRef] [PubMed]
5. Paquette, M.R.; Zhang, S.; Baumgartner, L.D. Acute effects of barefoot, minimal shoes, and running shoes on lower limb mechanics in rear and forefoot strike runners. *Footwear Sci.* **2013**, *5*, 9–18. [CrossRef]
6. McCallion, C.; Donne, B.; Fleming, N.; Blanksby, B. Acute Differences in Foot Strike and Spatiotemporal Variables for Shod, Barefoot or Minimalist Male Runners. *J. Sports Sci. Med.* **2014**, *13*, 280.
7. Sinclair, J. Effects of barefoot and barefoot inspired footwear on knee and ankle loading during running. *Clin. Biomech.* **2014**, *29*, 395–399. [CrossRef]
8. Squadrone, R.; Gallozzi, C. Biomechanical and physiological comparison of barefoot and two shod conditions in experienced barefoot runners. *J. Sports Med. Phys. Fit.* **2009**, *49*, 6–13.
9. LaPorta, J.W.; Brown, L.E.; Coburn, J.W.; Galpin, A.J.; Tufano, J.J.; Cazas, V.L.; Tan, J.G. Effects of different footwear on vertical jump and landing parameters. *J. Strength Cond. Res.* **2013**, *27*, 733–737. [CrossRef]
10. Zech, A.; Argubi-Wollesen, A.; Rahlf, A.-L. Minimalist, standard and no footwear on static and dynamic postural stability following jump landing. *Eur. J. Sport Sci.* **2015**, *15*, 279–285. [CrossRef]
11. Sinclair, J.; Hobbs, S.J.; Selfe, J. The influence of minimalist footwear on knee and ankle load during depth jumping. *Res. Sports Med.* **2015**, *23*, 289–301. [CrossRef]
12. Shultz, S.J.; Schmitz, R.J.; Tritsch, A.J.; Montgomery, M.M. Methodological considerations of task and shoe wear on joint energetics during landing. *J. Electromyogr. Kinesiol.* **2012**, *22*, 124–130. [CrossRef] [PubMed]
13. Hall, J.P.L.; Barton, C.J.; Jones, P.R.; Morrissey, D. The Biomechanical Differences Between Barefoot and Shod Distance Running: A Systematic Review and Preliminary Meta-Analysis. *Sports Med.* **2013**, *43*, 1335–1353. [CrossRef] [PubMed]
14. Kerrigan, D.C.; Franz, J.R.; Keenan, G.S.; Dicharry, J.; Della Croce, U.; Wilder, R.P. The effect of running shoes on lower extremity joint torques. *PM R J. Inj. Funct. Rehabil.* **2009**, *1*, 1058–1063. [CrossRef] [PubMed]
15. Bonacci, J.; Vicenzino, B.; Spratford, W.; Collins, P. Take your shoes off to reduce patellofemoral joint stress during running. *Br. J. Sports Med.* **2014**, *48*, 425–428. [CrossRef]
16. Mcgee, K.J.; Burkett, L.N. The National Football League combine: A reliable predictor of draft status? *J. Strength Cond. Res.* **2003**, *17*, 6–11. [CrossRef]
17. Harry, J.R.; Paquette, M.R.; Caia, J.; Townsend, R.J.; Weiss, L.W.; Schilling, B.K. Effects of footwear condition on maximal jumping performance. *J. Strength Cond. Res.* **2015**, *29*, 1657–1665. [CrossRef]
18. Smith, R.E.; Paquette, M.R.; Harry, J.R.; Powell, D.; Weiss, L.W. Footwear and sex differences in performance and joint kinetics during maximal vertical jumping. *J. Strength Cond. Res.* **2020**, *34*, 1634–1642. [CrossRef]
19. Chowning, L.D.; Krzyszkowski, J.; Harry, J.R. Maximalist shoes do not alter performance or joint mechanical output during the countermovement jump. *J. Sports Sci.* **2020**, in press. [CrossRef]
20. Esculier, J.-F.; Dubois, B.; Dionne, C.E.; Leblond, J.; Roy, J.-S. A consensus definition and rating scale for minimalist shoes. *J. Foot Ankle Res.* **2015**, *8*, 42. [CrossRef]
21. Lake, J.; McMahon, J. Within-subject consistency of unimodal and bimodal force application during the countermovement jump. *Sports* **2018**, *6*, 143. [CrossRef] [PubMed]
22. Bates, B.T. Scientific basis of human movement. *J. Phys. Educ. Recreat.* **1977**, *48*, 70. [CrossRef]
23. Higgins, S. Movement as an emergent form: Its structural limits. *Hum. Mov. Sci.* **1985**, *4*, 119–148. [CrossRef]
24. Bates, B.T.; Dufek, J.S.; James, C.R.; Harry, J.R.; Eggleston, J.D. The Influence of Experimental Design on the Detection of Performance Differences. *Meas. Phys. Educ. Exerc. Sci.* **2016**, *20*, 200–207. [CrossRef]
25. Bates, B.T. Single-subject methodology: An alternative approach. *Med. Sci. Sports Exerc.* **1996**, *28*, 631–638. [PubMed]
26. Bates, B.T.; James, C.R.; Dufek, J.S. Single subject analysis. In *Innovative Analyses of Human Movement*; Stergiou, N., Ed.; Human Kinetics: Champaign, IL, USA, 2004; pp. 3–28.
27. Hermens, H.J.; Freriks, B.; Merletti, R.; Stegeman, D.; Blok, J.; Rau, G.; Disselhorst-Klug, C.; Hägg, G. SENIAM 8 European Recommendations for Surface ElectroMyoGraphy. *Roessingh Res. Dev.* **1999**, *8*, 13–54.
28. Harry, J.R.; Blinch, J.; Barker, L.A.; Krzyszkowski, J.; Chowning, L. Low pass filter effects on metrics of countermovement vertical jump performance. *J. Strength Cond. Res.* **2020**, in press. [CrossRef]
29. Chappell, J.D.; Creighton, R.A.; Giuliani, C.; Yu, B.; Garrett, W.E. Kinematics and electromyography of landing preparation in vertical stop-jump: Risks for noncontact anterior cruciate ligament injury. *Am. J. Sports Med.* **2007**, *35*, 235–241. [CrossRef]
30. Harry, J.R.; Barker, L.A.; Paquette, M.R. A Joint Power Approach to Identify Countermovement Jump Phases Using Force Platforms. *Med. Sci. Sports Exerc.* **2020**, *52*, 993–1000. [CrossRef]

31. Dowling, J.J.; Vamos, L. Identification of kinetic and temporal factors related to vertical jump performance. *J. Appl. Biomech.* **1993**, *9*, 95–110. [CrossRef]
32. Moir, G.L. Three different methods of calculating vertical jump height from force platform data in men and women. *Meas. Phys. Educ. Exerc. Sci.* **2008**, *12*, 207–218. [CrossRef]
33. Harry, J.R.; Eggleston, J.D.; Lidstone, D.E.; Dufek, J.S. Weighted vest use to improve movement control during walking in children with autism. *Transl. J. Am. Coll. Sports Med.* **2019**, *4*, 64–73.
34. Bates, B.T.; Dufek, J.S.; Davis, H.P. The effect of trial size on statistical power. *Med. Sci. Sports Exerc.* **1992**, *24*, 1059–1065. [CrossRef] [PubMed]
35. Dufek, J.S.; Bates, B.T.; Stergiou, N.; James, C. Interactive effects between group and single-subject response patterns. *Hum. Mov. Sci.* **1995**, *14*, 301–323. [CrossRef]
36. Harry, J.R.; Eggleston, J.D.; Dunnick, D.D.; Edwards, H.; Dufek, J.S. Effects of Task Difficulty on Kinematics and Task Performance during Walking Workstation Use. *Transl. J. Am. Coll. Sports Med.* **2018**, *3*, 74–84.
37. Bates, B.T.; Osternig, L.R.; Mason, B.R. Variations of velocity within the support phase of running. *Sci. Athl.* **1979**, *20*, l985.
38. Scholes, C.J.; McDonald, M.D.; Parker, A.W. Single-subject analysis reveals variation in knee mechanics during step landing. *J. Biomech.* **2012**, *45*, 2074–2078. [CrossRef]