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Original Research

Four weeks of training with simple postural instructions changes trunk posture and foot strike pattern in recreational runners

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ABSTRACT

Objectives: Previous studies showed that adopting forward trunk lean and forefoot strike patterns may reduce risk of running-related knee injuries. However, the process of learning such forms is unclear. The purpose of the study was to investigate the effects of a 4-week training using simple postural instructions to elicit these changes.
Design: Longitudinal intervention study.
Setting: A training included postural instructions: 1) lean your trunk forward, and 2) land on the front part of your feet.
Participants: Eighteen recreational runners.
Main outcome measures: Participants were assessed prior to training (PRE), immediately after the instructions (iPST), during training at 2 weeks (2WK) and 4 weeks (4WK), and 7–10 days after the conclusion of training (RET). Assessment consisted of running trials performed at self-selected and controlled speeds, during which the trunk and foot strike angles were assessed.
Results: Comparing to PRE, forward trunk angle significantly increased by approximately 3.5° and foot strike angle by approximately 7° at 2WK, 4WK and RET.
Conclusions: A 4-week training with simple postural instructions induced significant changes in trunk and foot strike patterns in recreational runners. Future study is needed to develop clinical therapeutic protocols for runners with and at risk of running-related knee injuries.

1. Introduction

Running for sport, general fitness, weight loss, and conditioning for other sporting activities has become increasingly popular in recent years. There has been a greater than 120% increase in U.S. marathon finishers in the past decade.("Running USA Annual Marathon Report," 2016) More than 36 million people in the United States run for exercise or sport as of 2013 and 19 million running events finishers were reported("State of the Sport - US Road Race Trends," 2016). With an increasing number of runners, the incidence of injuries has also been on the rise. One recent study reported that half of all runners sustain at least one running-related overuse injury within the last year(Goss & Gross, 2012). The knee is the most commonly injured joint in marathon runners with yearly injury rates reported to be as high as 90%(Fredericson & Misra, 2007).

Running, as a natural progression of motor development, is typically mastered in children by age 5(Thalen & Smith, 1996). Repetitive locomotor activities such as running develop stable and preferred coordinated movement patterns due to the high number of repetitions. As a person progresses toward adulthood, the pattern becomes durable. Since running results in a high number of repetitive movements, reducing the stress experienced by the knee during each repetition may decrease the risk of overuse knee injuries(Nielsen et al., 2014; Teng & Powers, 2014). Furthermore,

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when a runner's running distance and training volume increases such as when preparing for a race, the chance of injury from small deficiencies in technique becomes greater (Taunton, MacLean, & Ryan, 2006). The stable neural pattern developed through this learning process can be difficult to change and may contribute to the increased running-related overuse knee injury risk(Nielsen et al., 2014; Saragiotto et al., 2014; Saragiotto, Yamato, Hespanhol, & Lopes, 2013). Artfully, developing and adapting to a new running form may increase the risk of injury, especially when it is a self-devised training while a structured training has a lower odds of injury(Jacobs & Berson, 1986; Linton & Valentin, 2018). Thus, a structured training not requiring excessive running volume is critical to reduce running-related knee injury risk.

Previous study has suggested that switching to a forefoot strike running pattern significantly reduced patellofemoral pain (PFP)(Cheung & Davis, 2011; Roper et al., 2016). Runners who run with a traditional rearfoot strike pattern exhibit a higher loading rate of vertical ground reaction force (vGRF), which results in an impact transient force at heel strike before reaching peak vGRF. In comparison, runners who land on the middle or front part of their foot tend to smoothly transition to peak vGRF without an impact transient feature and the associated high loading rate(Goss & Gross, 2012; 2013). A study investigating running mechanics with minimalistic shoes revealed a 3-time greater loading rate in rearfoot strikers than that in forefoot strikers(Willson et al., 2014). Greater loading rate in the early stance phase has been associated with increased running-related injury rate, such as PFP(Chan et al., 2018). An experiment showed that the impact force generally changed corresponding to foot strike patterns: high to low from obvious rearfoot strike to mid and forefoot strike(Mercer & Horsch, 2015). In addition, Cheung and Davis found that peak vGRF was decreased significantly when runners changed from a rearfoot strike to a forefoot strike pattern(Cheung & Davis, 2011).

Changing trunk posture has also been proposed to alter GRF and knee joint stress during running. Moving trunk forward shifts the GRF closer to the axis of knee joint and therefore relieve the load bore by knee(Roberts & Belliveau, 2005). Teng and Powers showed that increasing forward trunk flexion alone by even as little as 7.2° can significantly reduce the stress of the knee during the stance phase of running(Teng & Powers, 2014). Additionally, the authors reported that knee extensor energy absorption decreased by up to 23.3% while hip extensor muscle activity increased by up to 140% in runners with a more forward-flexed trunk posture(Teng & Powers, 2015).

Runners who adopt a combined more forward lean trunk posture and more forefoot strike patterns exhibited impact reduction measured by vGRF, loading rate and maximum braking force compared to runners who are rearfoot strikers(Goss, 2012; Goss & Gross, 2012). Increasing trunk flexion and changing from rearfoot to mid- or forefoot strike pattern have been demonstrated to be effective in decreasing knee stress during running, decreasing patellofemoral injury and therefore, knee pain(Arendse et al., 2004; Cheung & Davis, 2011; Davis, 2014; Teng & Powers, 2014). In the evidence, authors proposed that the decreased risk of knee injury from changing running form is due to the shift of mechanical stress away from the knee by forward trunk lean, as well as decreased vGRF loading rate during foot strike(Cheung & Davis, 2011; Teng & Powers, 2014, 2015).

Training to correct small biomechanical deficiency in movement patterns during running may lower the knee injury-related risk factors. However, given the evidence of potential benefits of running form modification for reducing biomechanical risk factors, little is known about whether the modification is trainable with simple postural cues as is typical in clinical physical therapy practice. Therefore, the purpose of this study was to analyze the effects of simple postural instructions on producing trunk forward lean and foot striking pattern in recreational runners during a 4-week training. We hypothesized that, first, after receiving the simple instructions, the participants will adopt an increased trunk flexion angle and ankle plantar flexion angle at initial contact, and decreased peak vGRF and loading rate when compared to before training. Second, participants will retain the modified running form and beneficial biomechanical changes in a retention test without instructions.

2. Methods

2.1. Participants

Eighteen recreational runners were recruited based on the following criteria: 1) between 18 and 45 years old, 2) injury-free at the time of the study, and 3) run at least 5 miles or 3 times per week. Exclusion criteria included: 1) any experience with barefoot, minimalist footwear, or posture-related running training (e.g. ChiRunning), 2) previous orthopedic surgeries that permanently alter musculoskeletal structures (e.g. joint replacement, anterior cruciate ligament reconstruction, discectomy), 3) any major injuries or conditions that prevent running within the previous 6 weeks, and 4) any current injuries or conditions that may prevent running safely on a treadmill. An interview by one of the investigators and a written questionnaire was given to help determine the eligibility of the participant. Prior to participation, an investigator verbally explained the purpose and procedure of the study. If the potential participant was interested in participating, informed consent approved by a University Institutional Review Board for Biomedical Research, was obtained.

2.2. Instrumentation

Running trials were collected using a Vicon Bonita 12-camera motion capture system (Oxford Metrics, Oxfordshire, UK) and Nexus software collecting at 200 Hz. Trunk angle was defined as the orientation of the trunk in relation to the global coordinate system. The kinematics of the trunk was determined by using a reflective marker cluster plate, which included four markers placed on the back between the first and the fifth thoracic spines (Fig. 1). A forceplate-instrumented treadmill (Bertec Corp., Columbus, OH) was utilized for running and the collection of GRF data sampled at 2000 Hz.

Using the digital motion-capturing system, each reflective marker was labeled corresponding to its anatomical landmark and each running trial was edited to include 10 consecutive complete steps. These labeled files were then transferred to the Visual 3D software (C-Motion, Rockville, MD) where each trial was checked to ensure labeling was accurate before the biomechanical variables of interest were computed.

2.3. Procedure

Participants were assessed prior to training (PRE), immediately after receiving instructions (iPST) on day 1, during training at 2 (2WK) and 4 (4WK) weeks, and 7–10 days after the conclusion of training (RET). Instructions were reinforced during the 2WK and 4WK visits (Fig. 2). During all testing sessions, runners wore running shoes of their own.

During the PRE test, participants ran on the treadmill with their habitual running form. The runners were given a 5-min warm up at a gradually increasing pace and then asked to run for 2 min at a comfortable self-selected speed which he or she would use during a training run, during which the running trials are collected. The

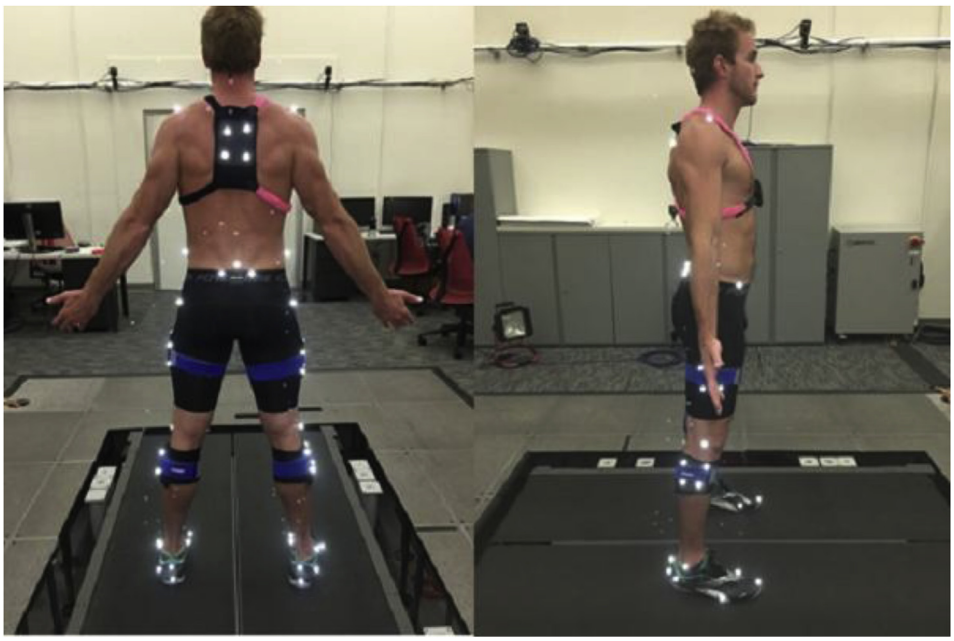

Fig. 1. Coronal and sagittal plane views of marker placement.

participants were then asked to run at a standardized speed of 2.5 m/s for another 2 min, in which the running trials were collected. At each running speed, three running trials of 20 s were collected without the runners' knowledge of data collection. Once the participants completed the PRE assessment, they were given a 10-min rest. During this time, the participants were given postural instructions and verbally repeated these instructions back to an investigator–"lean your trunk forward" and "land on the front part of your foot". Immediate after receiving the instructions (iPST), participants were reassessed using the same protocols as described in PRE.

Participants were asked to practice the cues and record their weekly running mileage and time on a pamphlet given to each participant that also included a reminder of the postural instructions. Sessions 2WK and 4WK followed the same assessment protocol. RET test consisted of the same running protocol without the running form instructions being reinforced, allowing assessment of retention of the learned movement pattern 7–10 days after the conclusion of training.

To measure the effect of only the simple postural cues, no explicit feedback regarding a participant's performance and form was given, the instruction instead focused on the reinforcing the 2 specific running cues.

2.4. Data analysis

The biomechanical variables of interest included sagittal trunk angle, foot strike angle, peak vGRF, and vGRF loading rate during early contact. Initial contact was defined as the first frame that vGRF exceeds 20 N for more than 140 continuous frames(Zeni, Richards, & Higginson, 2008). Trunk angle was calculated as averaged angle of the trunk segment relative to the global vertical axis in the sagittal plane in stance phase. Foot strike angle (ankle angle at initial contact in the sagittal plane) was analyzed as an indicator of strike pattern. Altman and Davis showed that the foot strike angle at initial contact is significantly correlated with strike index, the gold standard measurement for strike pattern quantified by the location of the center of pressure (COP) relative to the length of the foot. The authors showed that 85% of the variance in foot strike angle can be explained by the strike index, indicating that foot strike angle can be used as a valid estimator of strike pattern(Altman & Davis, 2012). Peak vGRF was determined as the maximal vGRF during a stance phase. Vertical loading rate was extracted between 20% and 80% of the impact transient phase (defined as from initial contact to the first impact peak). In trials with no apparent first impact peak, the loading rate was determined from 3% to 12% of the full stance phase(Goss & Gross, 2013). Since increased cadence may lead to vGRF-related variables such as decreased peak vGRF and decreased impact peak (Heiderscheit, Chumanov, Michalski, Wille, & Ryan, 2011; Lenhart, Thelen, Wille, Chumanov, & Heiderscheit, 2014; Willy, Willson, Clowers, Baggaley, & Murray, 2016), we also calculated the cadence to monitor this potential confounding factor. Biomechanical data were obtained and averaged over 5 consecutive strides for each trial. Foot strike angle was obtained from dominant leg only. Customized MATLAB (MathWorks Inc., Natick, MA) codes were used to perform the data extraction. Mean values from the 3 collected trials were used for statistical analysis.

2.5. Statistical analysis

One-way repeated measures ANOVAs with time (testing sessions) as the repeated factor were performed for self-selected and 2.5 m/s running speeds. Mauchly's Test of Sphericity was used to determine compound symmetry. When Mauchly's Test result was significant, Greenhouse-Geisser adjusted statistics were reported. When significant ANOVA main effects were detected, Bonferonni post-hoc analyses were conducted. Significance level for all analyses was set at 0.05. Data was analyzed using SPSS Statistics version 22 (IBM Corp., Armonk, NY).

3. Results

Participants' anthropometric characteristics were presented in Table 1. The running speeds selected by participants showed high consistency across different test sessions, where the coefficient of variation was 2%.

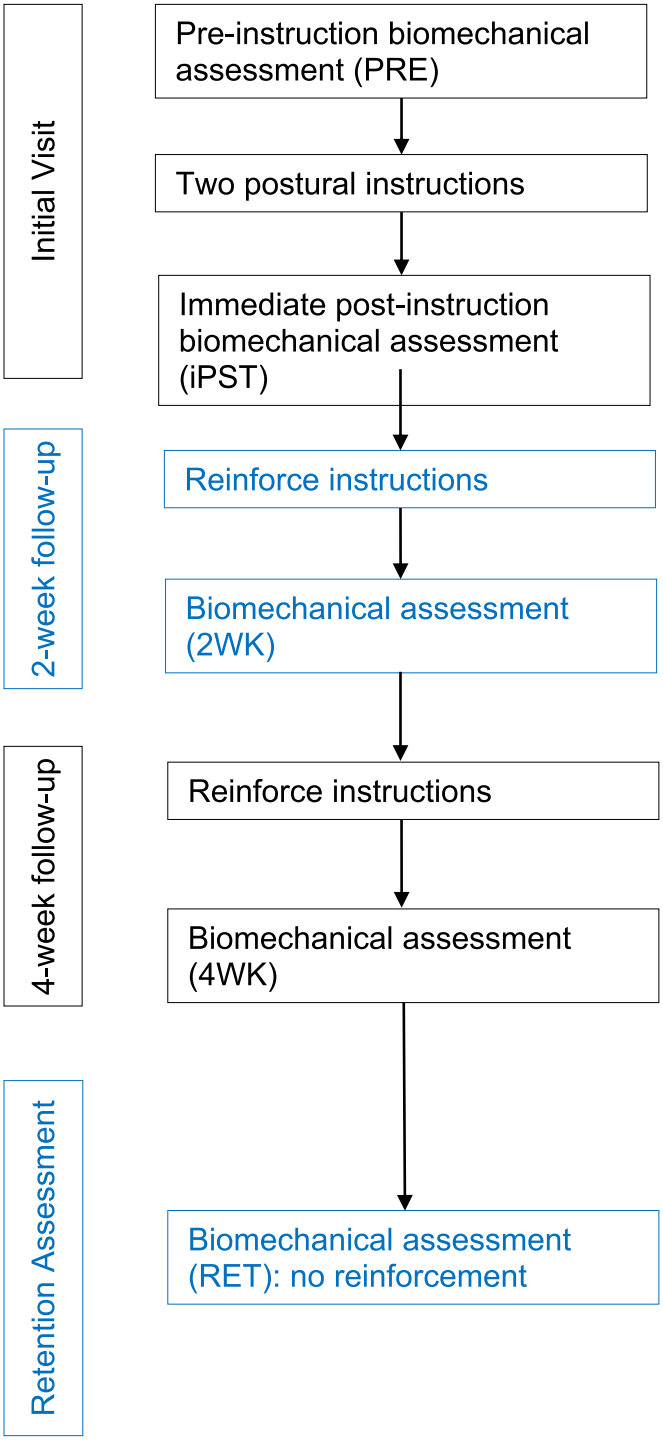

Fig. 2. Protocol timeline.

3.1. Kinematic variables

For averaged trunk angle at 2.5 m/s running speed, significant differences in trunk flexion across sessions was observed ($p = 0.001$). Bonferonni post-hoc showed that participants in PRE exhibited significantly less forward trunk flexion angle (more upright) than all other sessions. In self-selected speed, significant time effect on trunk angles ($p = 0.005$) was also detected. Bonferroni post-hoc comparison showed that the mean trunk angle of PRE was significantly smaller than iPST and 4WK (Table 2 & Fig. 3).

Table 1
Baseline demographics, self-reported running distance, and self-selected speed for tests*.

Characteristics	
Gender (male/female), n	7/11
Age, y	28.5 ± 6.1
BMI, kg/m^2	22.8 ± 2.6
Weekly mileage during study, mi	9.33 ± 4.79
Self-selected speed†, m/s	2.82 ± 0.06

Abbreviations: BMI, body mass index. *Values are mean ± SD unless otherwise indicated. †Mean self-selected speed across all 5 testing sessions.

At 2.5 m/s running speed, foot strike angle at initial contact was significantly different among test sessions ($p = 0.001$) with PRE being the lowest (more dorsiflexion) compared to all other sessions. Overall, participants demonstrated significantly greater ankle plantar flexion angle with training, from 5.18-degree dorsiflexion in PRE, to less dorsiflexion in iPST (0.65°), and plantar flexion in 2WK, 4WK, and RET (−2.23, −1.5, −2.49° respectively). At self-selected speed, a significant main effect on foot strike angle was also observed ($p = 0.033$), demonstrating a trend toward plantar flexion after training. Nevertheless, post-hoc analyses did not show statistically significant difference in foot strike angle comparing 2WK, 4WK and RET to PRE ($p = 0.238$, 0.406, 0.319 respectively) (Table 2 & Fig. 4).

3.2. Ground reaction force and cadence

No significant changes in mean peak vGRF over time were observed (self-selected speed, $p = 0.644$; 2.5 m/s, $p = 0.187$; Table 2). GRF loading rate also showed no significant changes overtime at both running speeds (self-selected speed, $p = 0.424$; 2.5 m/s, $p = 0.839$; Table 2). There was no significant change in cadence over time (self-selected speed, $p = 0.638$; 2.5 m/s, $p = 0.226$).

4. Discussion

This is one of the first training studies aimed to examine the effects of specific postural instructions on running form modifications (i.e. trunk and foot strike patterns). The training consisted of 3 instruction sessions over 4 weeks with simple postural cues regarding trunk posture and foot strike pattern. In addition to monitoring changes in running form during the training period, we also examined the retention of modified running form in a test without cuing after the conclusion of training. Our findings supported that when trained with simple postural cues, recreational runners can learn a new running form of increased trunk flexion and mid-to forefoot strike pattern. These learned patterns were effectively retained. However, we did not observe significant changes in the GRF profiles in this group of runners.

Based on our results, the trunk flexion angle increased significantly from PRE to iPST, 2WK, 4WK, and RET. Specifically, the mean trunk flexion angle in RET reaches 9.47°, which is approximately 2.78° more than PRE at self-selected speed; at 2.5 m/s, a 3.21-degree increase from PRE to RET was observed. Teng and Powers reported that a difference of 7.2 degrees of trunk flexion resulted in 23.3% lower energy absorption and 13.3% lower energy generation of knee extensors versus participants with a more upright trunk posture(Teng & Powers, 2015). Furthermore, a 6.8-degree more trunk flexion from natural posture significantly reduced patellofemoral joint reaction force by 5.3%, patellofemoral joint stress by 6% during running, and 7.1% less knee extensor moment at the time of

Table 2
Trunk angle, foot strike angle, vertical ground reaction force, and loading rate across all participants during 2.5 m/s trials and self-selected speed*.

	Trunk Angle, °	Foot strike Angle, °	Peak vGRF, BW	Loading Rate, N/ms
2.5 m/s				
PRE	6.78 ± 5.78	−5.18 ± 3.79	2.38 ± 0.46	14.27 ± 2.79
iPST	9.15 ± 5.51‡	−0.65 ± 6.61‡	2.44 ± 0.49	14.26 ± 3.34
2WK	10.08 ± 3.87‡	2.23 ± 6.57‡	2.43 ± 0.52	14.15 ± 3.15
4WK	10.05 ± 5.15‡	1.50 ± 6.42‡	2.43 ± 0.55	14.30 ± 2.69
RET	9.99 ± 4.32‡	2.49 ± 6.30‡	2.40 ± 0.52	13.68 ± 3.39
Self-selected Speed				
PRE	6.69 ± 6.10	−3.42 ± 5.80	2.49 ± 0.57	17.18 ± 6.02
iPST	9.76 ± 6.18‡	−1.19 ± 7.62	2.52 ± 0.55	16.94 ± 6.07
2WK	8.36 ± 4.74	2.59 ± 5.36	2.51 ± 0.54	17.25 ± 6.32
4WK	9.94 ± 5.24‡	2.00 ± 6.57	2.48 ± 0.57	16.60 ± 6.13
RET	9.47 ± 4.81	1.96 ± 7.29	2.49 ± 0.56	16.94 ± 6.49

Abbreviation: vGRF, vertical ground reaction force; BW, body weight; PRE, prior to training; iPST, immediate after instructions; 2WK, 2 weeks; 4WK, 4 weeks; RET, retention, one week after the conclusion of training. *Values are mean ± SD. Positive value in foot strike angle represents plantar flexion; negative value represents dorsiflexion. ‡Significant difference from PRE. One-way repeated analysis of variance compared with PRE by Bonferroni post-hoc comparison. Significant level was set at 0.05.

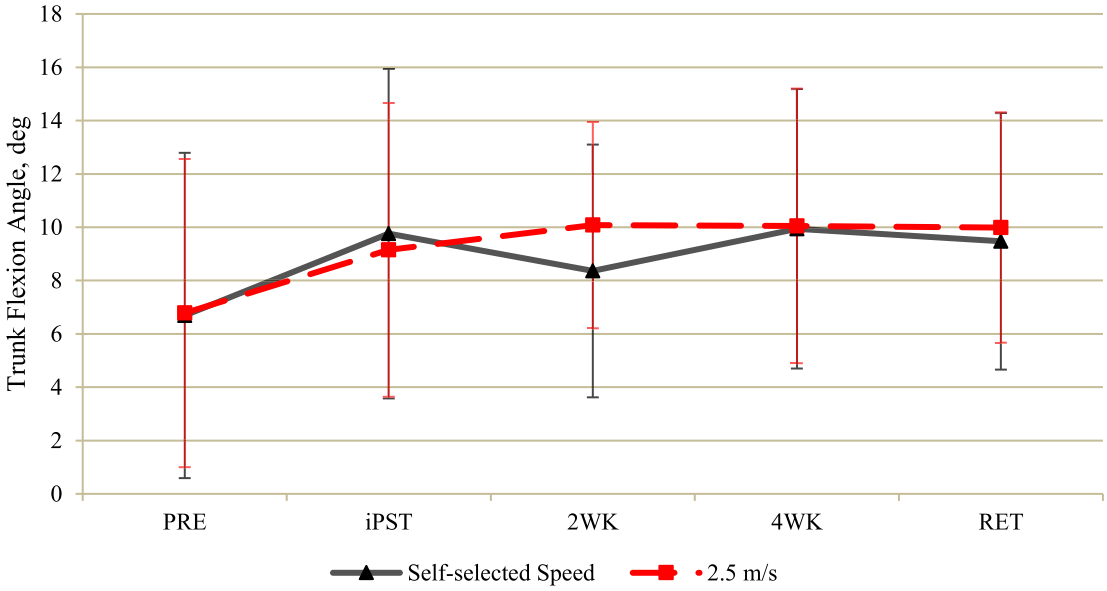

Fig. 3. Trunk flexion angle at self-selected speed and 2.5 m/s.

peak patellofemoral joint stress(Teng & Powers, 2014). When comparing mean trunk flexion angles across conditions, we observed only about 3-degree increase. Additionally, we did not measure knee kinetics but measured peak vGRF and loading rate. The smaller changes in trunk forward lean and the inconsistency of kinetic outcome measurements made it difficult to compare this study to the work done by Teng and Powers. Nevertheless, despite the nonsignificant vGRF-related results, a forward trunk lean may still be beneficial because the mechanism underlying the reduced knee extensor moment by forward trunk lean is the shortened effective moment arm of GRF to the knee joint(Roberts & Belliveau, 2005). Previous study has shown that the resultant knee joint moment may decrease without significant changes in peak vGRF magnitude(Braunstein, Arampatzis, Eysel, & Brüggemann, 2010).

For foot strike angle, significant time main effects in both speeds were observed, revealing an increased plantar flexion angle over time. Our participants ran with 3–5-degree ankle dorsiflexion during PRE, gradually transforming to more than 2 degrees of plantar flexion at 2WK, preserving the plantar-flexed pattern throughout the rest of the training and also RET. As previously suggested, forefoot strikes can be determined by foot strike angles greater than 1.6°, midfoot strikes between −8 and 1.6°, rearfoot strikes by less than −8°(Altman & Davis, 2012). Thus, our participants appeared to have switched from a midfoot to a forefoot strike pattern with the simple postural instructions. Our data suggested that the forefoot strike pattern began to emerge at 2WK and was retained beyond the conclusion of training. Shih et al. suggested that the average loading rate and peak instantaneous loading rate were significantly higher in rearfoot strikers than in forefoot strikers(Shih, Lin, & Shiang, 2013). The rearfoot strikers in their study performed on average 10.8 degrees of dorsiflexion at initial contact; the forefoot strikers performed 10 degrees of plantar flexion. Comparing the expression from our runners to those in Shih et al.'s study, it is perhaps the differences of foot strike angle extent from rearfoot to forefoot strike (−5 to 2 vs −10.8 to 10) contribute to the inconsistent findings in GRF(Shih et al., 2013).

Current research on running kinetics suggested that when runners land on their heels, there is a spike in vGRF known as the impact transient, followed by a small decrease as the runner rolls forward, and a second peak during push off(Lieberman et al., 2010). When runners adopt a forefoot strike pattern, there is typically only one peak, which may be slightly higher or lower than the peaks of impact transient, but average vGRF and loading rate may be less(Altman & Davis, 2010; Bishop, Fiolkowski, Conrad, Brunt, &

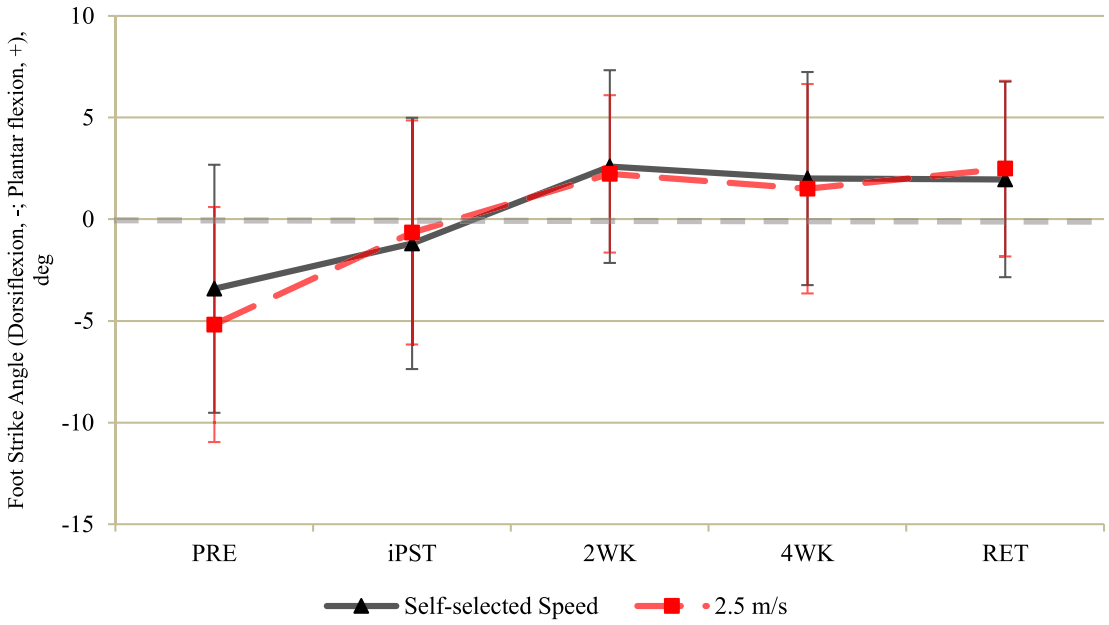

Fig. 4. Foot strike angle at self-selected speed and 2.5 m/s. The horizontal dashed line (0°) indicates neutral ankle plantar/dorsi-flexion.

Horodyski, 2006; Crowell & Davis, 2011). Some studies observed that a forefoot or midfoot strike pattern results in lower loading rates, lower maximum braking forces, and fewer number of impact transients but peak vGRF does not change(Cheung & Davis, 2011; Goss & Gross, 2012). However, some suggested that midfoot or forefoot strike patterns result in less peak vGRF(Arendse et al., 2004). A recent study identified a new foot strike pattern, based on its specific COP trajectory, as atypical rearfoot strike(Breine, Malcolm, Frederick, & De Clercq, 2014). During initial contact, atypical rearfoot strikers located the COP at the rearfoot but then moved anterior-laterally to midfoot and toes in a very short period, opposing to the anterior-medial movement observed in typical rearfoot strikes(Breine et al., 2014, 2017). Consequently, atypical rearfoot strike showed the highest peak vertical instantaneous loading rate across all foot strike patterns, but at the same time showed 3.1° ankle plantar flexion rather than dorsiflexion at initial contact(Breine et al., 2017). With the updated knowledge, rearfoot strikes do not always correspond to dorsiflexed foot strike angles but still display disadvantaging vGRF patterns. In other words, alteration in foot strike angles does not necessarily depict the vGRF pattern.

While changes in trunk posture and foot strike patterns were observed in the current study, we must be cautious of the potential injurious effect resulting from modifying running forms. These strategies may reduce the mechanical load off the knee, however other joints in the lower extremity (i.e. hip and ankle) may experience increase strain, and therefore potentially more susceptible to injuries. Running with forefoot strike showed higher ankle contribution in terms of greater plantar flexor moment, Achilles tendon force and strain(Kulmala, Avela, Pasanen, & Parkkari, 2013; Perl, Daoud, & Lieberman, 2012; Williams, McClay, & Manal, 2000). Other literature reported that increased trunk lean did not increase ankle plantar flexor moment, but it increased loading at the hip(-Teng & Powers, 2015). Since ankle has to contribute a lot in energy generation and absorption during running compared to hip and knee (Heiderscheit et al., 2011), it might be better to move the load to hip from an injury prevention perspective.

Our findings supported that the trunk lean and foot strike patterns during running are modifiable through simple instructions without explicit feedback provided to the runners. Running programs such as ChiRunning and Pose Method employ relatively complex instructions to runners. For example, ChiRunning requires runners to focus on whole body posture, trunk lean, foot strike pattern, and core muscles while running ("Five Elements of ChiRunning," 2018); Pose Method instructs runners to pay attention to the alignment of multiple joints simultaneously during running.("Pose Method® of Running Technique," 2018) We believe that too many movement foci could be mentally overwhelming. Meanwhile, abstract instructions such as "run tall" or "use pose-fall-pull technique" may confuse the runners("Five Elements of ChiRunning," 2018; "Pose Method® of Running Technique," 2018). Both of these issues may lead to ineffective learning and longer learning period. Most of the specific running form training programs are longer with more feedback during training. These programs typically involve hours of coaching, practice, and verbal and video-augmented feedback in addition to months of personal practice in order to achieve the anecdotally ideal running form and a consistent forefoot strike pattern(Agresta & Brown, 2015; Goss & Gross, 2012). While regarding the running volume, recent studies providing postural cues plus mirror feedback successfully elicited running form modification in about 40 km of running(Roper et al., 2016; Willy, Scholz, & Davis, 2012). In current study, a 4-week training program with simple postural cues without explicit feedback and mostly unsupervised practice, averaged 60 km running volume is capable of significantly altering the running form but not the vGRF and loading rate.

Feedback is an important factor in learning. In the current study, we chose not to provide explicit feedback to the runners to mirror the typical clinical scenario where real-time, quantitative feedback on running kinematics and vGRF is not available. Instead, runners were instructed to adjust their running form based on perceived comfort, flexibility, and individual interpretation of cues. A systematic review has revealed that augmented real-time visual and auditory feedback providing kinetic information such as GRF is effective in modulating loading rate and impact force during running(Agresta & Brown, 2015). The current study provided an additional perspective that explicit feedback is not necessary to induce small but lasting learning effects in a familiar movement

pattern such as running. These findings are useful in scenarios where technology-assisted feedback is not feasible.

The following limitations should be considered when interpreting the findings of this study. First, since we did not control the running footwear, wearing cushioned shoes may mask the vGRF changes induced by the strike pattern changes. However, controlling the shoe type may have the participants run in a shoe that they are not familiar with which can cause altered running pattern, too. Second, only recreational runners were included. For advanced or elite runners, they may have adopted a more fixed running form that can be more difficult to change compare to recreational runners. Lastly, the two instructions are both internally focused, guiding participant's attention to their own body movements. This may not be able to elicit maximal learning capacity and may actually interfere with movement automaticity(Wulf, Shea, & Lewthwaite, 2010). Existing evidence has demonstrated that instructions with an external focus guiding performers' attention to intended movement outcome, enhances motor performance and learning relative to internal focus instructions(Wulf, 2013). Despite the deemed “simple” instructions, runners may interpret the cues in their own way and adjust their running form differently. More research is needed to investigate how motor learning factors, such as forms of instruction, feedback, self-efficacy, and practice pattern affect running form re-education. A longer follow-up duration and a test incorporating cognitive tasks may serve as transfer tests to further examine the learning effect. Large-scale longitudinal studies are needed to determine the effectiveness of this type of running form modification training on reducing the risk of running-related knee injuries.

5. Conclusion

Simple postural instruction can induce significant changes a person's running form with greater trunk flexion and ankle plantar flexion angles after a 4-week intervention. However, our findings showed that the kinematic changes did not directly translate to reduced impact force and loading rate. Clinicians should carefully consider the movement instructions used to effect changes in running form. Future study is needed to examine the effects of training parameters including time, feedback and different types of instruction.

Conflict of interest

None declared.

Ethical statement

Participant assent was collected prior to the commencement of testing. Ethical approval was granted by the institutional ethics committee in accordance with the declaration of Helsinki. All procedures were conducted in accordance with those stated to ensure ethical compliance at all time.

Ethical approval

The study protocol was approved by the University of Nevada Las Vegas Institutional Review Boards. All participants provided informed consent to the work.

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