Journal of Sports Sciences
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rjsp20

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Published online: 04 Nov 2014.

To cite this article: Jocelyn F. Hafer, Allison M. Brown, Polly deMille, Howard J. Hillstrom & Carol Ewing Garber (2015) The effect of a cadence retraining protocol on running biomechanics and efficiency: a pilot study, Journal of Sports Sciences, 33:7, 724-731, DOI: 10.1080/02640414.2014.962573

To link to this article: http://dx.doi.org/10.1080/02640414.2014.962573

Journal of Sports Sciences, 2015
Vol. 33, No. 7, 724–731, http://dx.doi.org/10.1080/02640414.2014.962573

The effect of a cadence retraining protocol on running biomechanics and efficiency: a pilot study

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(*Accepted 1 September 2014*)

Abstract
Many studies have documented the association between mechanical deviations from normal and the presence or risk of injury. Some runners attempt to change mechanics by increasing running cadence. Previous work documented that increasing running cadence reduces deviations in mechanics tied to injury. The long-term effect of a cadence retraining intervention on running mechanics and energy expenditure is unknown. This study aimed to determine if increasing running cadence by 10% decreases running efficiency and changes kinematics and kinetics to make them less similar to those associated with injury. Additionally, this study aimed to determine if, after 6 weeks of cadence retraining, there would be carryover in kinematic and kinetic changes from an increased cadence state to a runner's preferred running cadence without decreased running efficiency. We measured oxygen uptake, kinematic and kinetic data on six uninjured participants before and after a 6-week intervention. Increasing cadence did not result in decreased running efficiency but did result in decreases in stride length, hip adduction angle and hip abductor moment. Carryover was observed in runners' post-intervention preferred running form as decreased hip adduction angle and vertical loading rate.

Keywords: *step rate, training intervention, running mechanics, running injury, stride frequency*

1. Introduction

Running is a popular activity as evidenced by the almost 14 million road race finishers in the United States in 2011 (Running USA: Statistics, 2013). While many enjoy the health benefits of this form of exercise, 24–65% of runners sustain an injury annually (Macera et al., 1989). Most of these injuries are categorised as overuse injuries, with patellofemoral pain syndrome, iliotibial band syndrome and tibial stress fractures being three of the most common running injuries (Taunton et al., 2002). Previous studies have tied these injuries to particular alterations in kinematics and kinetics. These three injuries have been associated with increased peak hip adduction angle (Noehren, Davis, & Hamill, 2007; Noehren, Pohl, Sanchez, Cunningham, & Lattermann, 2012; Pohl, Mullineaux, Milner, Hamill, & Davis, 2008; Willson & Davis, 2008), and tibial stress fractures have also been associated with increased tibial acceleration and vertical loading rate (Milner, Ferber, Pollard, Hamill, & Davis, 2006). These variables may be affected by interventions aimed at altering running form. An intervention that may be effective at modifying running mechanics associated with injury is to increase running cadence.

Previous studies have shown that increasing cadence at a constant speed (or implementing an intervention that leads to this) reduced the magnitude of loading variables that have been associated with stress fractures (Derrick, 2004; Derrick, Hamill, & Caldwell, 1998; Edwards, Taylor, Rudolphi, Gillette, & Derrick, 2009; Hamill, Derrick, & Holt, 1995; Heiderscheit, Chumanov, Michalski, Wille, & Ryan, 2011; Hobara, Sato, Sakaguchi, Sato, & Nakazawa, 2012). A study by Heiderscheit et al. found that increasing cadence resulted in decreased heel strike distance (a correlate of stride length), decreased peak vertical ground reaction force and decreased peak hip adduction,

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hip flexion and knee flexion angles as well as an increase in knee flexion angle at initial contact (Heiderscheit et al., 2011). It is notable that these changes are in the opposite direction of the aberrant mechanics associated with patellofemoral pain syndrome (Willson & Davis, 2008), iliotibial band syndrome (Noehren et al., 2007) and tibial stress fractures (Pohl et al., 2008). An acute intervention by Giandolini et al. found that increasing cadence resulted in decreased centre of mass vertical displacement, but found no differences between normal and increased cadence running in peak vertical ground reaction force or vertical loading rate (Giandolini et al., 2013). While it has been shown that an acute trial of increased cadence can potentially decrease injurious kinematics and kinetics such as abnormal hip adduction, impact force and knee flexion at initial contact (Heiderscheit et al., 2011; Hobara et al., 2012), it is unknown if runners will maintain these biomechanical changes over the course of an extended intervention. Additionally, it is not known what effect increased cadence has on running efficiency in the long term.

Previous multi-week gait retraining intervention studies have demonstrated the feasibility of improving potentially injurious running biomechanics. Potentially beneficial mechanical alterations have been observed after employing feedback interventions and Pose Method running techniques including decreases in loading rate, impact peak, peak positive acceleration (Crowell, Milner, Hamill, & Davis, 2010; Giandolini et al., 2013), hip adduction, hip internal rotation (Noehren, Scholz, & Davis, 2011), stride length and vertical oscillation (Dallam, Wilber, Jadelis, Fletcher, & Romanov, 2005). However, where oxygen uptake has been measured in interventions, the results have been conflicting, with some studies showing no change in efficiency and others reduced efficiency (Cavanagh & Williams, 1982; Dallam et al., 2005; Messier & Cirillo, 1989). Furthermore, the retraining methods in these studies required feedback mechanisms that are not available to the average runner (e.g. accelerometers, visual feedback, Pose Method instructor).

Increasing running cadence is an intervention which runners can implement easily and, because of the mechanical changes caused by increased running cadence, it has the potential to be a successful intervention for recovering from and preventing overuse running injuries. Moreover, if a cadence intervention can reduce potentially injurious biomechanics without adverse effects on running efficiency, runners will more likely adopt these gait alterations as a long-term injury–prevention strategy. Therefore, the aim of this study was to determine if a retraining protocol employing increased cadence results in a decrease in potentially injurious kinetics and kinematics while maintaining running efficiency in a group of healthy runners. The purpose of this pilot study was to test the potential effectiveness of an un-coached, runner-motivated intervention that, if successful, could be extended to larger populations of injured or previously injured runners in future work. We hypothesized that an acute increase in running cadence will lead to running mechanics that are less similar to those tied to injury, specifically increased knee flexion angle at initial contact, decreased ankle flexion (dorsiflexion) angle at initial contact, decreased heel strike distance and peak hip adduction angle, decreased peak hip extensor and abductor moments, decreased knee extensor moment, increased peak ankle plantar-flexor moment and decreased vertical loading rate while leading to decreased running efficiency (defined here as increased oxygen uptake at a set running speed). Additionally, we hypothesised that after 6 weeks of a cadence retraining protocol, runners will have incorporated kinematic and kinetic changes into their preferred running form with no decrease in running efficiency.

2. Methods

The study protocol was approved by the institutional review board for human participants research.

2.1. *Participants*

Participants were recruited through contact with local running coaches, running clubs, flyers posted in gyms and by word of mouth. Inclusion criteria included the following: no musculoskeletal injuries in the previous 12 months, currently running at least 15 miles/week, being a rear-foot striker as confirmed by investigator observation and having a preferred running cadence of 75–85 strides/min. This cadence range was set to select for runners with what clinicians and running coaches would describe as low cadence. Before enrolment, all runners were screened for preferred running pace and cadence.

To determine preferred pace and cadence, runners were asked to run on a treadmill at a pace they would select for a typical comfortable run. Runners with a cadence between 75 and 85 strides/min were invited to participate. A runner's cadence at enrolment was used as the preferred cadence from which the retraining cadence was determined, and pace at screening was used as the pace for all data capture sessions. Participants provided informed consent upon enrolling in the study.

2.2. *Procedure*

Data were captured at two time points: before and immediately after a 6-week cadence retraining intervention. All participants completed a questionnaire at the initial visit to document current training volume and regimen, race history and injury history. A physical therapist performed a basic biomechanical evaluation on all participants at the first visit to rule out structural or functional abnormalities. This evaluation included lower extremity joint passive range of motion, strength as assessed by manual muscle testing and specific tests for iliotibial band and hip flexor tightness. A brief evaluation was also performed at the follow-up visit to determine if there were any clinically relevant changes. Motion capture and metabolic data were captured at both visits.

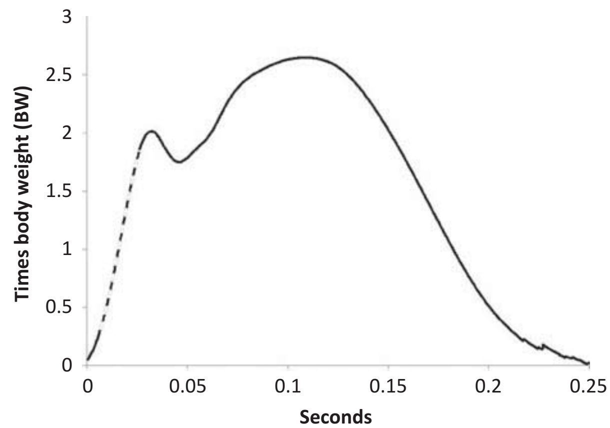

Figure 2. Example of vertical ground reaction force profile. The average vertical loading rate was calculated as the slope of the curve between 20% and 80% of the time until impact peak (shown as dashed section) (Milner et al., 2006).

2.2.1. Variables of interest. Variables of interest were selected because of their documented association with overuse injuries (Crowell et al., 2010; Edwards et al., 2009; Noehren et al., 2007; Willson & Davis, 2008). Kinematic outcome variables included centre of mass vertical displacement, heel strike distance (the horizontal distance between the centre of the pelvis and the ankle at initial contact (Figure 1)), stride length, knee flexion angle at initial contact, ankle dorsiflexion at initial contact and peak hip adduction angle. Kinetic outcome variables included internally referenced peak hip abductor moment, peak hip and knee extensor moments and ankle plantar-flexor moment, and vertical loading rate (Figure 2; as calculated by Milner et al. (2006)).

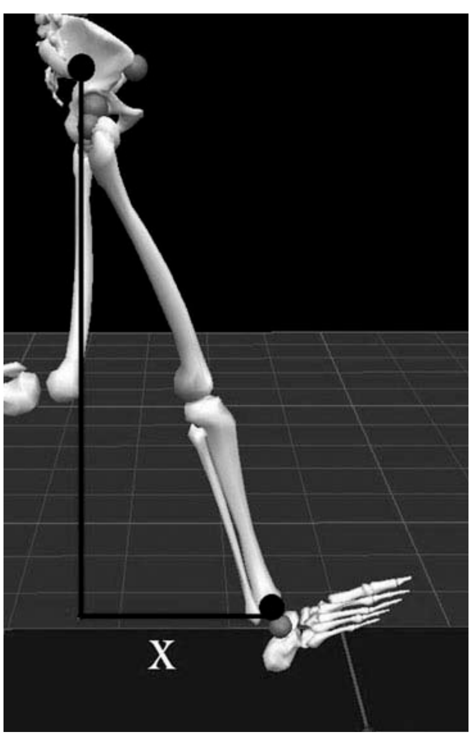

Figure 1. X depicts HSD, the horizontal distance between the centre of the pelvis and the ankle at initial contact.

2.2.2. Motion capture protocol. During both of the laboratory visits, kinematic and kinetic data were collected while the participant ran over ground across a 30 m runway at self-selected pace and cadence (as determined at enrolment screening). Pace was monitored using a Photogate system (SenSource, Youngstown, OH, USA). Trials were collected until a total of five complete strides per side of kinematic and kinetic data were captured. Acceptable trials were ±5% of the participant's preferred running pace from enrolment screening. To acclimate to increasing their running cadence, participants then ran on a treadmill for 3–5 min while listening to and matching a metronome set at 10% greater than their preferred cadence. Following this, overground trials were collected at the +10% cadence until a total of five complete strides per side of kinematic and kinetic data were captured while runners listened to and matched a metronome. Speed was monitored and controlled to match the original self-selected pace.

Kinematic data were captured at 120 Hz using a twelve-camera motion capture system (Motion Analysis Corporation, Santa Rosa, CA, USA) and passive retroreflective markers. Lower extremity kinematics were calculated based on a 54 marker, six degree of freedom markerset (Figure 3). A static calibration trial was used to calculate segment characteristics and joint centres. Hip joint centres were calculated by a regression equation based on the inter-anterior superior iliac spine distance (as recommended in OrthoTrak software, Motion Analysis Corporation, Santa Rosa, CA, USA), and knee joint centres were calculated as the midpoint

Figure 3. Marker set used for 3D motion analysis.

between the medial and lateral femoral epicondyles. Anatomical markers defined the trunk (right and left acromioclavicular joints and sacro-lumbar joint), pelvis (left and right anterior superior iliac spine and sacro-lumbar joint), thigh (hip joint centre and medial and lateral femoral epicondyles), shank (medial and lateral femoral epicondyles, tibial tuberosity, and medial and lateral malleoli) and foot (heel and first and fifth metatarsal heads). Between-day marker placement reliability has previously been reported to be acceptable, with the lowest ICC for the variables examined in this study being reported as 0.69 for peak hip adduction angle (Ferber, Noehren, Hamill, & Davis, 2010). In this study, between-day marker placement variation was also minimised by having the same, trained investigator place markers on all participants at both visits. To ensure consistent shoe conditions within each participant before and after 6 weeks of training, all motion data were captured while participants ran with laboratory-provided neutral running shoes (New Balance 1062, Boston, MA, USA). Kinetic data were captured concurrently at 4800 Hz using four force plates (Bertec Corp., Columbus, OH USA and AMTI, Watertown, MA, USA).

2.2.3. Motion capture data processing. Motion capture data were processed with a custom code written in LabView (National Instruments, Austin, TX, USA) and Visual 3D (C-Motion, Inc., Rockville, MD, USA). Kinematic and kinetic variables were smoothed using low pass fourth-order Butterworth filters at 8 Hz and 50 Hz, respectively. Kinematic and kinetic measures were calculated from five acceptable trials for each limb.

2.2.4. Metabolic Data Capture Protocol. After the motion capture protocol, participants completed metabolic energy expenditure testing to determine running efficiency. All measures were captured during treadmill running at the same pace that participants ran at during motion capture data collection. Oxygen uptake (VO2) was first measured during a participant's self-selected cadence and then at a cadence 10% higher than the participant's self-selected cadence. A metabolic cart (ParvoMedics, Sandy, UT, USA) was used to collect oxygen uptake data. Participants ran for 8 min or until they had completed 5 min in a steady state for each condition (self-selected and +10% cadence). Energy expenditure tests were conducted consecutively with no break between tests. Data for the second phase of the test were reported once steady state was reached after the participant's change in cadence. Running efficiency was taken as the average oxygen uptake per minute from the last 5 min of steady-state data.

2.2.5. Cadence retraining protocol. Upon completion of the initial visit, participants were given instructions for the cadence retraining period. The cadence retraining protocol was designed to mimic an informal intervention that a runner might undertake themselves. Participants received a 6-week training log to complete with their +10% cadence recorded on the log. Participants were informed about and given access to metronomes, music playlists consisting of songs with tempos at their +10% cadence and free-access phone and computer applications that provided these services. Each participant could use whichever tool they preferred for their training. To complete their training, runners were instructed to listen to and match the tempo of the audible tool they were using. None of the tools the participants used provided feedback on how well each participant was matching their prescribed cadence.

Participants were instructed to complete at least 50% of their weekly mileage at their +10% cadence and to record all training in the training log. Training could be completed during overground or treadmill running, whichever the participant preferred. A study investigator contacted each participant on a weekly basis to provide encouragement, monitor participants for injury and ensure adherence to the training protocol. Training logs were collected at the second visit.

2.2.6. Visit 2 protocol. The same procedures were followed for data collection at the second visit. Pace and +10% cadence were matched to the pace and +10% cadence selected at visit 1. Preferred cadence was not constrained at visit 2 to allow for observation of whether a runner's preferred cadence had changed from visit 1 to 2 as a result of the retraining period.

2.2.7. Statistics. As one participant dropped out during the retraining period due to a non-running-related injury, outcome variables were compared across two conditions (visit 1 only) for six participants and across four conditions (visits 1 and 2) for five participants.

Outcome variables were calculated for four conditions: visit 1 preferred cadence, visit 1 +10% cadence, visit 2 preferred cadence and visit 2 +10% cadence. Effect size was calculated for all variables for clinically relevant comparisons (visit 1 preferred versus +10% cadence, visit 1 +10% cadence versus visit 2 +10% cadence and visit 1 preferred versus visit 2 preferred cadence). Variables were compared using generalized estimating equations, including average values of each variable for each limb of all participants. For variables not associated with a limb (VO2, centre of mass vertical displacement, stride length), repeated measures ANOVAs were used to compare between conditions. Because of participant dropout, two sets of statistical analyses were run. The first set compares visit 1 preferred cadence to visit 1 +10% cadence for six participants. The second set compares all four conditions for the five participants who completed the study. Significance was set *a priori* at $P \leq 0.05$ for all analyses. Post hoc analyses with Bonferroni corrections to $P \leq 0.017$ were run for variables identified as significant.

3. Results

Twenty-six runners responded to recruitment attempts. Most were not eligible for inclusion due to running cadence over 85 strides/min or an injury in the last year. Eight runners met inclusion criteria. Of these eight runners, one became injured and one moved out of state before they could participate in visit 1 of the study. Six runners (age 31.0 ± 5.5 years, 1.76 ± 0.1 m, 70.7 ± 13.6 kg) enrolled in the study. Four participants were female. One participant did not complete the post-intervention visit due to a non-running-related injury. All participants were recreational runners training an average of 18.5 miles/week (s = 5.16). No runners reported running-related injuries during the retraining period.

At the initial visit, the six participants' overground cadence averaged 80.83 (s = 3.13) strides/min and 88.67 (s = 3.50) strides/min for preferred and +10% conditions, respectively. For the five participants who completed the study, visit 1 cadences were 82.88 (s = 4.01) strides/min and 89.91 (s = 1.84) strides/min for preferred and +10% conditions, respectively. At visit 2, these five participants' cadence averaged 84.87 (s = 6.24) strides/min and 91.00 (s = 2.13) strides/min for preferred and +10% conditions, respectively. This demonstrates a significant increase in preferred cadence from visits 1 to 2 ($P < 0.001$, effect size 0.39). Through analysis of training logs, all participants reported completing at least 50% of their weekly mileage at their assigned +10% cadence (average: 61%, range: 50–80%).

3.1. *Visit 1, preferred cadence* versus *±10% cadence*

An increase in running cadence resulted in changes in mechanics in the expected direction without a change in oxygen consumption. Running efficiency was not significantly different between conditions. Centre of mass vertical displacement, heel strike distance, stride length, ankle dorsiflexion angle at initial contact, hip adduction angle, peak hip abductor moment, peak knee extensor moment and peak ankle plantar-flexor moment were significantly decreased at the +10% cadence condition (Table I).

3.2. *Visit 1* versus *visit 2*

After 6 weeks of a cadence retraining intervention, runners had a small but significant increase in preferred running cadence. This small increase in preferred cadence translated into decreases in ankle dorsiflexion at initial contact, peak hip adduction angle and vertical loading rate. Running efficiency was not significantly different between any conditions. Differences seen between preferred and +10% conditions were similar to the visit 1 comparison for all variables, with the exception of peak hip abductor moment (Table II).

4. Discussion

The purpose of this study was twofold: (1) to determine if changes in mechanics with increased running cadence come at the cost of running efficiency and (2) to examine if acute adaptations to increased running cadence are assimilated into a runner's preferred running form after 6 weeks of a simple intervention with little outside feedback. Our aim was to determine if an intervention that mimics the self-imposed and self-monitored interventions many recreational runners undertake has the potential to modify potentially injurious mechanics, and if typical runners are able to adopt these changes in mechanics without a cost to efficiency. The results of this pilot study support the hypothesis that, after 6 weeks of cadence retraining, runners alter their preferred running form in a manner that would potentially decrease the risk of overuse injury without decreasing their running efficiency.

Table I. Running energy expenditure, kinematics and kinetics at baseline for six participants.

	Visit 1 preferred cadence		Visit 1 +10% cadence			
	Average	*s*	Average	*s*	*P*-value	Effect size
VO2 (mL/kg*min)	38.1	4.7	38.4	5.3	0.259^	0.07
CVD (m)	0.12	0.01	0.10	0.00	**0.004^**	4.00
HSD (m)	0.24	0.06	0.23	0.06	**0.002**	0.17
SL (m)	2.44	0.47	2.19	0.34	**0.009^**	0.62
KFIC (°)	6.0	4.6	7.1	3.9	0.222	0.26
AFIC (°)	13.3	3.9	11.4	3.7	**0.021**	0.49
HA (°)	12.0	1.7	10.4	1.6	**<0.001**	0.96
HAM (Nm/kg)	−1.8	0.3	−1.7	0.3	**0.018**	0.30
HEM (Nm/kg)	−1.7	0.7	−1.8	0.5	0.409	0.17
KEM (Nm/kg)	−2.5	0.5	−2.1	0.5	**<0.001**	0.79
APM (Nm/kg)	−2.7	0.2	−2.6	0.1	**0.003**	0.65
VLR (BW/s)	49.8	16.6	47.7	13.9	0.305	0.14

Notes: CVD: centre of mass vertical displacement; HSD: heel strike distance; SL: stride length; KFIC: knee flexion at initial contact; AFIC: ankle dorsiflexion at initial contact; HA: peak hip adduction angle; HAM: peak hip abductor moment; HEM: peak hip extensor moment; KEM: peak knee extensor moment; APM: peak ankle plantar-flexor moment; VLR: vertical loading rate.
^indicates repeated measures comparison.
Bold values indicate statistically significant difference.

Table II. Final efficiency, kinematic and kinetic results for five participants; post hoc: a = visit 1 preferred cadence different from visit 1 +10% cadence, b = visit 1 +10% cadence different from visit 2 preferred cadence, c = visit 2 preferred cadence different from visit 2 +10% cadence, d = visit 1 preferred cadence different from visit 2 +10% cadence, e = visit 1 +10% cadence different from visit 2 +10% cadence, f = visit 1 preferred cadence different from visit 2 preferred cadence.

	Visit 1 Preferred cadence		Visit 1 +10% cadence		Visit 2 Preferred cadence		Visit 2 +10% cadence				Effect Size		
	Average	*s*	Average	*s*	Average	*s*	Average	*s*	*P*-value	post-hoc	a	e	f
VO2 (mL/kg*min)	36.4	3.7	36.8	4.1	36.7	4.1	36.8	4.1	0.952^		0.11	0.00	0.07
CVD (m)	0.11	0.01	0.10	0.00	0.11	0.02	0.09	0.00	**0.002^**	a,d	1.63	2.82	0.00
HSD (m)	0.23	0.04	0.21	0.04	0.22	0.04	0.20	0.03	**<0.001**	a,b,c,d	0.50	0.29	0.25
SL (m)	2.29	0.33	2.07	0.21	2.20	0.33	2.05	0.24	**0.002^**	a,c,d	0.81	0.09	0.27
KFIC (°)	4.3	2.2	6.1	3.5	3.4	4.6	4.8	5.3	**<0.001**	a,b,c	0.65	0.31	0.26
AFIC (°)	12.6	4.0	11.5	4.1	10.8	3.1	9.7	3.1	**<0.001**	a,d,e,f	0.28	0.49	0.52
HA (°)	12.3	1.7	10.5	1.8	11.3	1.4	10.2	1.9	**<0.001**	a,b,c,d,f	1.06	0.16	0.65
HAM (Nm/kg)	−1.8	0.2	−1.8	0.3	−1.7	0.1	−1.7	0.2	0.257		0.32	0.41	0.63
HEM (Nm/kg)	−1.5	0.5	−1.7	0.3	−1.3	0.3	−1.4	0.4	0.195		0.39	0.71	0.48
KEM (Nm/kg)	−2.4	0.5	−2.0	0.3	−2.3	0.6	−2.2	0.5	**<0.001**	a,c	1.06	0.50	0.07
APM (Nm/kg)	−2.7	0.1	−2.6	0.1	−2.6	0.2	−2.6	0.2	**0.048**	a,d	0.67	0.07	0.39
VLR (BW/sec)	48.0	17.7	46.1	14.7	44.1	16.6	46.2	13.7	**<0.001**	f	0.12	0.01	0.23

Notes: Effect size reported for clinically relevant comparisons. ^indicates repeated measures comparison. Bold values indicate statistically significant difference.

Overall, this pilot study supports the limited literature documenting that increased running cadence reduces kinematics and kinetics that have been tied to overuse running injuries (Heiderscheit et al., 2011). Additionally, this study demonstrates the ability of healthy runners to adhere to an uncoached cadence retraining intervention and that runners can modify their preferred running mechanics within 6 weeks. The acute (visit 1) differences seen with increased cadence are similar to mechanical changes seen with earlier cadence and barefoot running interventions (Chumanov, Wille, Michalski, & Heiderscheit, 2012; Giandolini et al., 2013; Heiderscheit et al., 2011; Squadrone & Gallozzi, 2009). In this group of experienced but not highly trained runners, increasing cadence by 10% did not decrease running efficiency. Previous studies of either highly trained (Cavanagh & Williams, 1982) or novice (Messier & Cirillo, 1989) runners found little to no change in running efficiency with changes in running cadence or form. This study supports those works in showing that the running efficiency of recreational runners may not be decreased by small changes in running form.

The initial changes seen in running mechanics support our hypothesis that increased cadence would result in decreases in potentially injurious running mechanics. Decreases in centre of mass vertical displacement and stride length are thought to result in increased attenuation of impact forces in the body, while decreases in heel strike distance and ankle dorsiflexion at initial contact can place the leg in a more spring-like landing posture (e.g. more flexed knee and possible neutral or plantar-flexed ankle at initial contact), leading to better distribution of impact through the lower extremity. Longer stride lengths (Edwards et al., 2009) and a more extended knee at initial contact (Derrick, 2004) can lead to greater forces transmitted to the tibia and, presumably, a greater risk of tibial stress fractures. An increase in peak hip adduction is thought to contribute to more strain on tissues that cross the hip laterally (e.g. the iliotibial band) either because of greater magnitude of loading, higher loading rate (Hamill, Miller, Noehren, & Davis, 2008) or a longer time spent in a strained alignment. Decreased knee extensor moments correspond to decreased forces being transmitted across the knee and, in combination with changes in knee kinematics, may reduce patellofemoral contact forces (Lenhart, Thelen, Wille, Chumanov, & Heiderscheit, 2014) and the chance of patellofemoral pain.

Supporting our initial hypothesis, several changes that were seen between preferred and +10% cadence conditions in visit 1 carried over to preferred cadence in visit 2. Most promising are the significant decreases in peak hip adduction angle and vertical loading rate, because higher than average values of these variables have been measured in runners at risk for iliotibial band syndrome (Ferber et al., 2010; Noehren et al., 2007), with patellofemoral pain (Noehren et al., 2012; Willson & Davis, 2008) and with a history of tibial stress fractures (Milner et al., 2006; Pohl et al., 2008). While changes between pre- and post-intervention preferred running mechanics are not as numerous as those between preferred and +10% conditions, the average change in preferred cadence was only +2.4% for the entire group. This suggests that significant benefits may be possible with only a small change in running cadence.

While these results are derived from a small sample, the consistency and direction of the improvements in the kinematic and kinetic parameters across conditions are promising and support the need for future research. Several variables (heel strike distance, stride length, hip, knee and ankle moments) showed differences between the preferred and +10% cadence conditions at both visits 1 and 2 and also decreased modestly when comparing visits 1 and 2 preferred cadence conditions, but these differences did not reach statistical significance due to low power. Some variables also showed slight decreases from visit 1 +10% cadence to visit 2 +10% cadence, demonstrating that runners continue to adapt to intervention-imposed constraints past the acute stage. These trends suggest that longer or more structured interventions may lead to additional changes in running mechanics.

While this study demonstrates that recreational runners are able to adopt the potentially beneficial mechanics of a simple cadence retraining intervention through a minimally monitored program, none of the runners in this study had a recent history of overuse injuries and therefore may have responded differently than runners who have symptoms of an overuse injury or who have a history of overuse injury. However, it is promising that healthy runners were able to complete this intervention without altering their training volume or sustaining running injuries, supporting the potential clinical effectiveness of this interventional approach. From some prospective studies, it may be inferred that historically uninjured runners possess mechanics that are closer to optimal compared with runners who will go on to be injured (Noehren et al., 2007). The presence of potentially injurious mechanics may leave these runners with more room for positive alterations in their running form, but this question would have to be answered by future studies. The findings of a reduction in potentially injurious mechanics in healthy runners' preferred running form without a decrease in running efficiency support investigation of cadence retraining interventions' effects on runners with or at risk of overuse injury.

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