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An Examination of Step Frequency and the Running Readiness Scale as Predictors of Running-Related Injury in Collegiate Cross-Country Athletes

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An Examination of Step Frequency and the Running Readiness Scale as Predictors of Running-Related Injury in Collegiate Cross-Country Athletes

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Purpose: The purpose of this study was to determine the relationship between step frequency and the Running Readiness Scale and the occurrence of a Running-Related Injury (RRI) in a Division III cross-country team. **Methods:** Each athlete was screened prior to the season for their step frequency at a preferred and pre-determined pace. Additionally, each athlete performed 6 musculoskeletal tests known as the "Running Readiness Scale" to assess body alignment, weight distribution, and muscular endurance. Each subject logged their training and competition schedule and injury history throughout the season using the Otterbein Run Tracker app. **Results:** Sixteen subjects completed data collection for the entire cross-country season. Six of the sixteen sustained a RRI (37.5%). The results of the study did not show a significant difference between the Running Readiness Scale assessment between injured and non-injured runners in this sample. **Conclusions:** The application of this study to a larger population of collegiate cross-country runners is needed to assess whether step frequency and the Running Readiness Scale can be used to predict injury risk in collegiate cross-country athletes. **Key Words:** *running related injury*

INTRODUCTION

In recent years, running has become a popular physical activity among a wide range of age groups as both an organized sport and a recreational activity. Unfortunately, one of the drawbacks of running is that it is an activity that often produces overuse injuries of the lower extremity. Various studies have estimated that between 27% and 70% of recreational and competitive distance runners respectively sustain an overuse running injury during any one year period.[1-3] One consensus definition of Running-Related Injury (RRI) is "running-related (training or competition) musculoskeletal pain in the lower limbs that causes a restriction on or stoppage of running (distance, speed, duration, or training) for at least seven days or three consecutive training sessions, or that requires the runner to consult a physician or other health professional".[4]

There are many proposed risk factors in the current literature that could predispose a runner to an overuse injury. These risk factors can be categorized as either training, anatomical, or biomechanical risk factors. Training variables that are usually identified as risk factors for overuse injuries include running distance, training intensity, rapid increases in weekly running distance or intensity, and stretching habits.[1, 3, 5] Some anatomical variables that may cause running injuries may include high longitudinal arches, increased or decreased ankle range of motion, leg length discrepancies, and lower extremity alignment abnormalities.[1, 6] Lastly, some possible biomechanical risk factors of overuse injuries in runners may include the magnitude of impact forces, increased loading on the medial side of the foot, and the magnitude of knee joint forces and movements.[1,7-10]

Excessive joint and muscle forces due to stride length, or conversely step frequency, may predispose a runner to sustaining an injury.[8] Many research studies in the current literature have examined the effects of step frequency manipulation on running mechanics. The consensus among many studies is that an increased step frequency results in a decreased center of mass vertical excursion, ground reaction force, shock attenuation, and energy absorbed at the knee, hip, and ankle joint.[8] The evidence found among these studies indicates that clinicians may be able to use the manipulation of step frequency as a method of treatment for RRIs.[11]

Lenhart, Thelen, and Heiderscheit[12] examined individual hip contributions throughout the stride cycle in a population of healthy adult recreational runners. This study specifically examined the effects of three different step rates (90%, 100%, and 110% of the healthy participants' preferred speed) on whole-body kinematics and ground reaction forces. This study found that a higher step rate resulted in an increase in hip flexor, hamstring, and hip extensor loading during swing ($p<0.05$), and decreased stance-phase loading of the gluteal muscles and the piriformis ($p<0.05$). The researchers concluded that these results may allow clinicians to improve treatment strategies for RRIs through gait retraining that includes training at higher step frequencies to reduce joint impact forces.

Other researchers have found evidence that increased step rate has beneficial outcomes for RRI reduction. Heiderscheit, Chumanov, Michalski, Wille and Ryan[8] examined the biomechanical effects of step rate alterations during running on the hip, knee, and ankle joints. This study instructed a pool of 45 healthy recreational runners to run at a constant speed for various step rates (preferred, ±5%, and ± 10%) and the 3-D kinematics and kinetics at each step rate were measured. The results of this study showed that a reduced step rate (by 10%) resulted in significantly more energy absorption at all joints ($p<0.01$). The collected data also supported that a decrease in step length, center of mass vertical excursion, breaking impulse, peak knee flexion angle, peak hip adduction angle, peak hip adduction, and hip internal rotation movements and mechanical energy absorption at the knee ($p<0.01$ for all variables) occurred during an increase in step rate. This study concluded that a small increase in step rate can significantly reduce joint loading, which may suggest that step manipulation would be beneficial for the prevention and treatment of common RRIs, especially in the knee and hip.

Additionally, research suggests that muscular weakness and abnormal running mechanics may also be a risk factor. Hreljac and Ferber[1] measured the hip strength of a group of runners with varying musculoskeletal injuries. The researchers found that the injured limb had significantly weaker hip abductor and hip flexor muscles than the healthy limb. The hip strength of the healthy limb was similar to the control group.

Ferber, Noehren, Hamill, and Davis[13] compared hip and knee running mechanics between female runners with no knee related running injuries and female runners who had a history of iliotibial band syndrome (ITBS). The study found the ITBS group to have statistically significant increased peak rearfoot invertor movement ($P=0.05$), peak hip internal rotation angle ($P=0.03$), and peak hip adduction angle ($P=0.05$) during stance phase.[13] These results suggest that these kinematic patterns cause increased stress on the IT band. The researchers of this study concluded that correction of abnormal lower extremity kinematics may decrease stress on the IT band and would therefore be beneficial to the treatment of ITBS. The gluteus medius abducts the hip and also assists with hip external rotation. Therefore, weakness of this muscle may cause more stress to the lower limbs while running due to increased hip adduction and hip internal rotation.[1] This hypothesis is supported in these studies, which suggest a relationship between hip muscle weakness and atypical running mechanics.

It is important to note that most of the work on RRIs has been conducted on healthy, adult recreational runners. The current research has not yet followed a sample of runners during a cross-country season to determine if there would be a significant difference in step

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frequency rates between injured and non-injured runners. Additionally, the Running Readiness Scale (RRS) is a newly formed screening technique that evaluates runners using common strength and endurance tests for the core and lower extremity. The tests on the RRS target the muscle groups and motor patterns that have been identified as risk factors for RRIs. The Running Readiness Scale needs continued validation within various running populations. The researchers determined that a study which targets a population of collegiate runners during their cross-country season was appropriate for adding validity to the current literature.

Therefore, the purpose of this study was to determine the relationship between step frequency, scores on the Running Readiness Scale, and injury rates among a collegiate cross-country team during a Fall competition season. The hypotheses of this study were that runners with higher step frequencies and runners with higher failure rates on the RRS would sustain more RRIs.

METHODS

The participants in this study were healthy volunteers who were members of a Division III collegiate cross-country team during their competitive Fall season. Subjects were contacted during a team meeting and asked to participate in the study. Twenty-nine out of the 41 members of the team (71%) agreed to participate. If the subjects completed the study, they were entered in a drawing to receive a gift card. A scheduled time was established for participants to run on the treadmill and complete the Running Readiness Scale exercise assessment in a controlled, laboratory setting.

At their arrival, each participant signed an informed consent and then completed warm up on the treadmill at a self-selected pace for five minutes. At the end of the five minutes, participants ran at a preferred pace for 3 minutes and at a test pace of 7.5 miles per hour for 3 additional minutes. Step rate (steps/min) were calculated for each pace (preferred and pre-determined) by counting the number of right foot strikes during a 30 second period and multiplying by four. Participants then completed the Running Readiness Scale assessment. The participants were given a pass or fail for each assessment. The Running Readiness Scale was developed to screen for muscular endurance and lower extremity dynamic control through the use of 6 screening tests that are evaluated on a nominal scale by a clinician. In past studies, drop jump tasks and single leg landing tasks have been used as screening tests for predicting ACL injury and patellofemoral pain syndrome. Decreased knee flexion, increased hip internal rotation, and increased knee valgus observed during these tasks has been linked to the development of knee injury.[14] The Running Readiness Scale assessment uses a similar method for injury prediction. This assessment is a series of screening tasks which includes step ups, hopping, wall sits, single leg squats, double leg squats, and a plank hold, each lasting one minute.

For the step ups, participants stepped up and down using an exercise step up approximately four inches above the ground. The double leg hops were done in place. The participants were instructed to hop up and down repeatedly on their toes. Participants held the wall sit with a stability ball between their back and the wall. For the single leg squats and double leg squats, participants were instructed to bend their knee to the beat of a metronome set to their step frequency. Participants performed the elbow plank holds on a floor mat. These tests assessed body alignment, weight distribution, and muscular endurance.

Throughout the season, the participants tracked their running and injury history daily using the Run Tracker app (Peekaboo Studios, Columbus, OH). Injury incidence studies also tend to rely on recall by participants. If an athlete sustains a season-ending injury, that is often not difficult to recall. However, relying on post-season fact checking or post-training interviews can become problematic with regard to the ability of subjects' to recall enough data about injuries that might have interrupted their training enough to actually qualify as a RRI. For the purposes of this study, an "app" was used by all subjects to log their running and training data daily.

Subjects were given a unique identifier number so their name was not linked to the data. If three consecutive days or at least seven days of restricted training were observed due to the same source of pain, or if the athlete consulted a health professional, injury incidence was recorded for the participant and the subject was considered "injured" for the purpose of this study. Runners who did not log three consecutive days or seven total days of restricted running due to the same injury source of pain were "non-injured". New data was downloaded and recorded every two weeks from the beginning to the end of the study. Data collection began in August and concluded in November at the end of the cross-country season.

Threats to the validity of this study were minimized by standardizing the testing conditions and using experienced researchers to run the testing. The researchers designated to collect step frequencies and conduct the exercise assessments did not change between study trials. In order to reduce researcher fatigue, study trials were scheduled so that researchers were not conducting consecutive tests longer than two hours. A qualified physical therapist who had participated in the reliability testing of the Running Readiness Scale served as the researcher conducting the Running Readiness Scale assessments. In order to most accurately interpret the results of the data, subjects entered specific information concerning their running history into the Run Tracker app. When subjects did not complete a scheduled workout, they indicated on the app the reason why they did not complete their run. If subjects did not complete a run due to injury, they would provide the injury location and would indicate if they consulted a medical professional. The subjects also indicated their gender on the app.

All data were analyzed using SPSS 22, (IBM, Armonk, NY). A paired t-test was conducted to determine if a significant difference existed between the running cadences of the subjects that sustained an injury and the injury free group (for both the preferred and test pace). A Chi-Square test was also conducted for each exercise assessment of the Running Readiness Scale to determine if a significant difference existed between the pass rates of the injured group and non-injured group. Statistical significance was set at $p \leq .05$ for all tests.

RESULTS

Twenty-nine subjects completed the pre-screening (18 females and 11 males). Six subjects made no entries into the Run Tracker app. Seven subjects tracked their running and injury history with the app for less than one month and two of these subjects sustained a RRI. Sixteen subjects tracked their data with the app for the entire cross-country season. Six of these 16 subjects sustained a RRI (37.5%). Five of the injured runners were female and one was male. Six of the non-injured runners were female and four were male. The average age of the injured runners was 20.17 years and the average age of the non-injured runners was 19.00 years.

At the participants' preferred pace, the mean cadence for the injured group was 179.5 steps/min and 172 steps/min for the non-injured group (Table 1). At the test pace, the mean cadence for the injured group was 182.5 steps/min and 176 steps/min for the non-injured group. There was not a significant difference in cadence between the injured and non-injured groups at the preferred or the test pace.

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	Preferred Pace Cadence (steps/min)	Test Pace Cadence (steps/min)
Injured Subjects (n=8)	179.5	182.5
Non-Injured subjects (n=10)	172	176

Table 1. Cadence **Note: steps were counted for each subject for one minute at their self-selected (preferred) treadmill pace and at 7.5mph (test pace)*

A Chi-Square test was performed for each test of the Running Readiness Scale to determine if there was a significant difference between the pass and fail rates for the injured group and non-injured group. No significant difference existed between the groups for any single Running Readiness Scale assessment (Table 2). For the step up assessment, two injured and five non-injured subjects failed the assessment. Out of all the subjects, 38.9% failed the step-ups, 55.6% failed the hopping assessment, 27.8% failed the wall sit assessment, 72.2% failed the single leg squat test, 50% failed the double leg squat assessment, and 55.6% failed the plank assessment.

	Step-Ups	Hopping	Wall Sits	SL Squats	DL Squats	Planks
Injured						
Pass	6 subjects	5 subjects	6 subjects	3 subjects	3 subjects	3 subjects
Fail	2 subjects	3 subjects	2 subjects	5 subjects	5 subjects	5 subjects
Non-injured						
Pass	5 subjects	3 subjects	7 subjects	2 subjects	6 subjects	5 subjects
Fail	5 subjects	7 subjects	3 subjects	8 subjects	4 subjects	5 subjects
Chi-Square	0.280	0.168	0.814	0.410	0.343	0.596

Table 2. Running Readiness Scale **Note: Six tests from the RRS & number of subjects that passed or failed the individual tests.*

CONCLUSIONS

The results of this study did not support the hypothesis that the non-injured athletes would have higher step frequencies and higher Running Readiness Scale pass rates for individual scale items. The data did not support that there was a significant difference between the preferred and test cadences of the injured and non-injured runners. For both the preferred pace cadence and the test cadence, the mean values were very similar for both groups. The collected step frequencies of the subjects suggest that collegiate cross-country athletes tend to have similar step cadences. Because of this lack of variation, step frequency may be an inconclusive variable to test when pre-screening for RRI risk in collegiate cross-country athletes. Step frequency may be a more effective pre-screening tool for recreational runners who are of various age groups and do not train together. This sample of subjects did train together frequently and the results of this study demonstrate that in fact this sample of subjects had a very similar cadence at the preferred and test pace.

There were no statistically significant differences between the injured and non-injured groups for the Running Readiness Scale assessments. More research is needed to determine if it is a useful pre-screening tool to utilize for RRI prediction in collegiate cross-country athletes. Additional analysis that would look at the tests in a more summative way might provide additional insight.

The researchers in this study made some assumptions. It was assumed that each participant gave a full effort during the Running Readiness Scale exercise assessment and that each participant provided an accurate and honest representation of their running history when completing the Run Tracker App.

Additionally, the results of this study found that 72.2% of total subjects failed the single leg squat assessment. The single leg squat assessment measures hip strength and coordination, as well as quadricep endurance.

An area of further research may be to determine whether a hip and quadricep strengthening program reduces the occurrence of RRIs amongst collegiate cross-country athletes. Also, studies which examine training or anatomical risk factors for RRIs may be beneficial for gaining further knowledge on the prevention and treatment of RRIs. Type of racing distance (e.g. long off-track or short track distances) as well as training with more than a 30% increase in weekly mileage have been shown to be related to RRI development.[10] The Run Tracker app may be a useful tool for finding relationships between rapid increases in training intensity and injury. A recent study conducted by Kuhman et al. compared ankle joint and ground reaction force variables between groups of injured and non-injured collegiate cross-country runners.[10] The results of this study found that ankle eversion range of motion was greater in uninjured runners, suggesting that greater ankle eversion ROM may reduce injury risk in collegiate cross-country athletes. Therefore, because this study did not examine anatomical risk factors, a study which compares measures such as ankle range of motion between a group of collegiate cross-country runners may be an area worth exploring.

RECOMMENDATIONS

In conclusion, the data does not support that step frequency and the Running Readiness Scale can be used as pre-screening tools to predict injury in collegiate cross-country athletes. However, this study followed a very small population of subjects. Further research is needed to apply the study to a wider population to increase the study's validity. The results of this study also suggest that further research is needed to explore the implications that training and anatomical variables have on the occurrence of Running-Related Injuries.

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