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Running injuries in novice runners enrolled in different training interventions: a pilot randomized controlled trial

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The purpose of this trial was to evaluate injury risk in novice runners participating in different strength training interventions. This was a pilot randomized controlled trial. Novice runners ($n = 129$, 18–60 years old, <2 years recent running experience) were block randomized to one of three groups: a "resistance" strength training group, a "functional" strength training group, or a stretching "control" group. The primary outcome was running related injury. The number of participants with complaints and the injury rate (IR = no. injuries/1000 running hours) were quantified for each intervention group. For the first 8 weeks, participants were instructed to complete their training intervention three to five times a week. The remaining 4 months was a maintenance period. Trial registration: NCT01900262. A total of 52 of the 129 (40%) novice runners experienced at least one running related injury: 21 in the functional strength training program, 16 in the resistance strength training program and 15 in the control stretching program. Injury rates did not differ between study groups [IR = 32.9 (95% CI 20.8, 49.3) in the functional group, IR = 31.6 (95% CI 18.4, 50.5) in the resistance group, and IR = 26.7 (95% CI 15.2, 43.2)] in the control group. Although this was a pilot assessment, home-based strength training did not appear to alter injury rates compared to stretching. Future studies should consider methods to minimize participant drop out to allow for the assessment of injury risk. Injury risk in novice runners based on this pilot study will inform the development of future larger studies investigating the impact of injury prevention interventions.

Scientific evidence for the benefits of aerobic exercise has continued to grow over the years. A recent meta-analysis demonstrates that regular running is associated with reduced body mass, resting heart rate and triglycerides, and increased maximal oxygen uptake and high density lipoprotein cholesterol (Hespanhol Junior et al., 2015). Despite the enormous health benefits, the majority of runners will experience a running related injury (Hespanhol Junior et al., 2015; Videbæk et al., 2015). Individuals that are new to running (novice runners) have been shown to have a higher incidence of running-related injuries than experienced runners (Videbæk et al., 2015). In addition to the short-term reduction in activity associated with an injury, some runners will lose motivation to run once exposed to an injury, possibly leading to long-term inactivity (Koplan et al., 1995; Lohmander et al., 2004). This may be particularly true for new runners who are returning to exercise after a period of inactivity and have yet to form consistent training habits involving physical activity. Prevention of running injuries for novice runners is important to enable these individuals to remain active and avoid comorbidities associated with inactivity, such as heart disease and obesity.

Interventions aimed at preventing running related injuries have aimed to alter risk factors associated with injury (van Mechelen et al., 1993; Buist et al., 2008). Previous randomized controlled trials (RCT) and quasi-experimental studies have demonstrated that running injury prevention interventions that reduced weekly running mileage or included a stretching warm up did not reduce the risk of injury in novice runners (van Mechelen et al., 1993; Buist et al., 2008). Another theory is that reduced muscular strength limits the ability to control movements at the joints, resulting in increased strain on the soft tissues and ultimately leading to injury. Some injury prevention interventions have focused on increasing the strength of the hip musculature for a "top down" approach to reduce movements at the joints and the associated injury risk (Hott et al., 2015; Palmer et al., 2015). However, knowledge can be gained from evaluating other strengthening interventions that may alter running mechanics and reduce injury risk. One form of strengthening that may be relevant is a "bottom up" approach focusing on the ankle musculature (Tiberio, 1987; Feltner & Macrae, 1994; Hollman et al., 2005; Nigg et al., 2006). Another approach may be to step away from isolated forms of joint muscle strengthening and incorporating functional sport-specific movement forms of strength training (Cates & Cavanaugh, 2009). Both resistance training at the ankle joint and functional sport-specific movement strength training, or neuromuscular training, have been shown to increase strength (Tropp & Askling, 1988; Feltner & Macrae, 1994; Heitkamp et al., 2001) and reduce lower extremity joint movements (Feltner & Macrae, 1994; Myer et al., 2006). However, the influence of these two different types of strength training on running injury incidence in novice runners is currently unknown.

Injury surveillance in novice runners requires detailed attention to the follow-up period and injury definition. For example, differences in injury rates between novice runners and experienced runners were found only with longer follow-up periods (1 year) as opposed to shorter follow-up periods (8–12 weeks) (Kluitenberg et al., 2015a). With respect to injury definition, an injury is typically defined based on a medical attention, full time loss from activity or a reduction in training volume injury definition (Bahr, 2009). The definition of injury can have a significant influence on the reported injury rates in a group of runners (Kluitenberg et al., 2015b). It is therefore important to consider the type of runners who are being evaluated when choosing the appropriate injury definition. For example, the injury proportions reported with the medical attention definition is low (0.9–15.6% on average) across all runners except for ultra-marathon runners (65.6% on average) (Kluitenberg et al., 2015a). Additionally, overuse injuries may be under-reported, as it is possible that individuals will continue to train without seeking medical attention, despite the presence of pain from an overuse injury (Junge & Dvorak, 2000; Bahr, 2009; Clarsen et al., 2012). In summary, the evaluation of an injury prevention intervention for novice runners requires follow-up for a sufficient duration (6 months–1 year) using an injury surveillance methodology that includes overuse symptoms (Clarsen et al., 2012).

Currently, there is little knowledge about the efficacy of either resistance strength training at the ankle or a functional sport-specific movement form of strength training to reduce the incidence of injury in novice runners. Therefore, the objectives of this pilot RCT are to compare injury incidence rates in healthy adult novice runners participating in an 8-week resistance ankle strengthening program, an 8-week functional sport-specific movement strength training program or a stretching control program. In this pilot study, it was hypothesized that the risk of injury in the resistance strength training group and the functional strength training group would be lower than the control stretching group.

Materials and methods

Study design & participant population

The current study was part of the Calgary Strength for Novice Runners Study, an RCT conducted in the Faculty of Kinesiology at the University of Calgary. The study design and procedures have described in detail previously (Baltich et al., 2014). All participants provided written informed consent in accordance with the University of Calgary's policy on research using human participants. This RCT has been registered with ClinicalTrials.gov (NCT01900262) and approval for this research project was obtained from the University of Calgary's Conjoint Health Research Ethics Board (Ethics ID: REB13-0153). Novice recreational runners were recruited for this study as they have been shown to have a higher risk of running related injuries (Macera et al., 1989; Rolf, 1995; Tonoli et al., 2010; Genin et al., 2011; Videbæk et al., 2015). Inclusion criteria included the following: (1) less than 2 years of recent weekly running exposure, (2) 18–60 years of age, (3) no pain or injury within 3 months of testing, (4) running is the primary form of exercise and (5) no weekly resistance band or functional strength training in the previous year. Participants were recruited through use of posters, university website advertisements, social media advertisements, and word of mouth. Participants were randomly assigned to one of three training groups: a resistance strength training group focusing on strengthening the ankle joint musculature, a functional sport-specific movement strength training group, or stretching control group. An unpredictable randomized allocation sequence was generated using a random allocation scheme (one block) with a 1:1:1 allocation ratio between the three groups. Randomization was not stratified by age or gender. After participants provided written informed consent and completed their baseline assessment, they sequentially drew a numbered, opaque, sealed envelope, and signed the back before opening the envelope to determine their group allocation.

Interventions

All exercise interventions were home based and have been described previously (Table 1) (Baltich et al., 2014). A warm-up routine consisting of aerobic activity, static and dynamic stretching was taught to participants in all three groups. For the stretching control group, participants completed this warm up for 25-min with no additional training. Stretching was chosen as a control intervention as it has previously been shown to have no protective effect in reducing the risk of running related injury (van Mechelen et al., 1993; Lauersen et al., 2014). The resistance strength training group and the functional strength training group were asked to complete this warm up for 5 min in addition to 20 min of group-specific exercises. For the resistance strength training group,

Table 1. Training routines for the control stretching, functional strength training, and resistance strength training groups. Adapted from (Baltich et al., 2014)

	Stretching control			Functional strength training							Resistance strength training		
	Aerobic warm up	Static stretch	Dynamic stretch	Stretch	Lunge	Squat	Hop	Single leg standing	Single leg standing	Jumps	Stretch	Resistance band	Isometric against wall
Weeks 1,2	5 min: side to side shuttle, high knee skipping, light running	10 min: groin, hamstring, quadriceps, calves	10 min: buttock kicks, leg swings	5 min: aerobic warm up, static & dynamic stretch	10 Reps: flat ground, forward & backward	10 Reps: flat ground, two feet	5 Reps: flat ground, two foot box hop	5 × 30 s: flat ground, eyes open	5 × 30 s: flat ground, eyes closed	20 Reps: flat ground, side to side	5 min: aerobic warm up, static & dynamic stretch	Red, 4 sets of 10	3 × 5 s
Weeks 3,4	5 min: side to side shuttle, high knee skipping, light running	10 min: groin, hamstring, quadriceps, calves	10 min: buttock kicks, leg swings	5 min: aerobic warm up, static & dynamic stretch	5 Reps: flat ground, lunge around the clock	10 Reps: BOSU ball, two feet	5 Reps: flat ground, one foot box hop	5 × 30 s: flat ground, trunk lean, eyes open	5 × 30 s: flat ground, trunk lean, eyes closed	5 Reps: flat ground, star form, alter feet	5 min: aerobic warm up, static & dynamic stretch	Green, 4 sets of 10	5 × 5 s
Weeks 5,6	5 min: side to side shuttle, high knee skipping, light running	10 min: groin, hamstring, quadriceps, calves	10 min: buttock kicks, leg swings	5 min: aerobic warm up, static & dynamic stretch	10 Reps: BOSU ball, forward & backward	10 Reps: Flat ground, one foot	10 BOSU ball, two foot hop	5 × 30 s: BOSU ball, eyes open	5 × 30 s: BOSU ball eyes closed	3 reps: flat ground, star form, one foot	5 min: aerobic warm up, static & dynamic stretch	Blue, 4 sets of 10	3 × 10 s
Weeks 7,8	5 min: side to side shuttle, high knee skipping, light running	10 min: groin, hamstring, quadriceps, calves	10 min: buttock kicks, leg swings	5 min: aerobic warm up, static & dynamic stretch	20 Reps: BOSU ball, forward & backward	10 Reps: BOSU ball, one foot	10 BOSU ball, one foot hop	5 × 30 s: BOSU ball, trunk lean, eyes open	5 × 30 s: BOSU ball, trunk lean, eyes closed	3 reps: flat ground, star form, one foot	5 min: aerobic warm up, static & dynamic stretch	Black, 4 sets of 10	5 × 10 s

participants completed a training program with elastic bands that increased in stiffness every 2 weeks for the first 8 weeks of the study. Participants in the functional strength training group were provided with a BOSU® ball (Hedstrom Fitness, Ashland, Ohio, USA) and asked to complete lunges, squats, hops, single leg standing and jumps. These exercises increased in difficulty every 2 weeks for the 8 week training period. Participants met in person with the study coordinator every 2 weeks to receive their new equipment and exercises. The 6-month follow-up period was split into a training period (8 weeks) and a maintenance period (16 weeks). All participants were instructed to complete their respective training protocol three to five times per week in addition to running at least once a week for the 8 week training period. Following the 8 week training period, participants were asked to complete their respective training protocol twice a week in addition to running at least once a week for the remaining 4 month maintenance period. Each participant received an instructional videotape as well as one-page summary sheets outlining their exercises. Participants were asked to report their training and running exposure (minutes) on a weekly online form. Participants were not aware of the content of the other interventions.

Outcome measures

All participants completed a baseline questionnaire including information about running experience (weeks of exposure, frequency per week, average weekly mileage, average training session duration), preferred running surface (e.g. grass, asphalt, trail, etc.), number of running shoes, frequency of replacing running footwear, motivation for running and history of previous injuries.

The primary outcome of this study was running related injury. A running related injury was defined as any musculoskeletal complaint of the lower extremity or lower back caused as a result of running that resulted in a restriction in running (running distance, duration) for at least 1 week (Buist et al., 2008). Participants were asked to only report injuries that they believed were a direct result of running. Injuries that they did not believe were caused from running were not reported. If a participant suffered from an injury that resulted in time loss from training for at least 1 week, they were instructed to contact the study coordinator to set up a visit with a physiotherapist at the University of Calgary. At this visit, the physiotherapist completed a clinical assessment. Non-running related injuries that were sustained in the 6 month study period were not included in the analyses.

Running exposure, training exposure and physical complaints related to running were self-reported online on a weekly basis through StudyTRAX, a web-based Electronic Data Capture system. Running logs included information regarding the number of running minutes and location (e.g. grass, track, treadmill, etc.) for each day of the week. Training exposure included the number of training sessions completed each week. Physical complaints were tracked using an overuse injury questionnaire (Clarsen et al., 2013). This questionnaire asked four questions, including the existence of a physical complaint that hindered running training, how much this complaint hindered weekly training distance and duration, and the extent of the pain associated with the physical complaint. Participants were specifically asked if they had any complaints at their ankle, knee, or hip. An 'other' category was provided for any physical complaints in other regions (e.g. lower leg, lower back, upper leg, foot, etc.). Anatomical location of the injury was self-reported and was not confirmed with a manikin or any other form of imagery. Messages were sent by email 1 day before the weekly due date to remind participants to complete the online form the following day. A reminder email was automatically sent if the form was not completed within 2 days of the due date. If runners did not complete the online form within 1 week of the initial email, they were contacted directly by phone to complete the form either online or over the phone. To reduce the chance of recall bias, participants were provided with a paper log identical to the online format to record their daily running and training exposure on a weekly basis.

Statistical analyses

This study was an exploratory investigation evaluating the injury incidence rate in novice runners enrolled in different exercise interventions. An exploratory power analysis was completed for the expected injury incidence proportions for this study based on previous studies investigating running injuries in untrained runners enrolled in running training programs (Bovens et al., 1989; Taunton et al., 2003). If the intervention groups should lead to a 50% reduction in the injury incidence and assuming the control group has an injury incidence of 40% (per 100 runners), 82 subjects would be needed in each group to achieve 80% statistical power with an $\alpha = 0.05$. Due to the lack of power, the injury outcome analyses for this pilot RCT was exploratory.

The injury incidence proportion (IP) was quantified as the proportion of runners that sustained at least one running injury during the 6-month follow-up period. The injury incidence rate (IR) was estimated for each group as the number of running related injuries per 1000 h of running exposure. Multiple injuries were taken into account in the calculation of the IR. The running hours until the time of injury as well as following the injury were also taken into account for the calculation of the IR. The number of physical complaints in each body region (lower extremity and lower back) was recorded. Weekly severity of each physical complaint was rated on a scale from 0 to 100 (0 = no complaint, 100 = full time loss with severe pain) as described previously (Clarsen et al., 2013) (Fig. 1). The week the physical complaint first appeared, as well as the average weekly severity associated with that complaint, was recorded for all injuries related to running. The amount of running reduction (minor, moderate, major, full time loss) was also recorded for all injuries from the physical complaint questionnaire. If a participant complained of discomfort at multiple anatomical regions, the physical complaint with the highest severity score was identified as the most severe running related injury.

Results

Population

For the 8 week exercise intervention period, nine runners (21%) in the functional strength training group, 15 runners (35%) in the resistance strength training group and 19 runners (44%) in the stretching control group dropped out prior to the completion of the 8-week training period (Fig. 2). An additional 11 runners (20 total, 47%) from the functional strength training group, four runners (19 total, 44%) from the resistance strength training group and three runners (22 total, 51%) from the stretching control group dropped out prior to the full 6 month completion date (Fig. 2). Baseline anthropometric

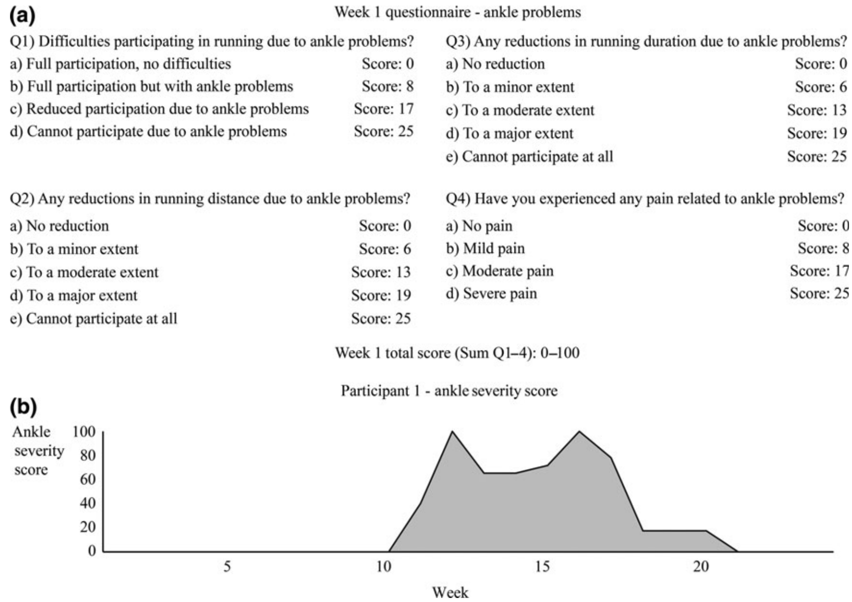

Fig. 1. (a) Example of an injury questionnaire for ankle complaints and (b) exemplary weekly severity score at the ankle joint for one participant.

and running experience characteristics for the participants that completed the 6 -month follow-up period as well as the participants that dropped out of the study are presented in Table 2. Baseline characteristics of those that dropped out of the study and those that remained in the study appeared similar between the three training groups.

Adherence training intervention

In the functional strength training group, 22 participants (51%) completed at least four sessions per week, 15 (35%) completed two to three sessions per week and six (14%) completed less than two sessions per week. For the resistance strength training group, 28 participants (65%) completed at least four sessions per week, 12 (28%) completed two to three sessions per week and three (7%) completed less than two sessions per week. For the control group, 24 participants (56%) completed at least four sessions per week, 13 (30%) completed two to three sessions per week and six (14%) completed less than two sessions per week.

Running related injuries

Of the 129 allocated novice runners in this study, 52 sustained a running-related injury. For the resistance training group, the 16 participants (37%) reported a running related injury. For the functional strength training group, 21 participants (48%) reported a running related injury, and for the control stretching group 15 participants (35%) reported a running related injury. For the participants that reported a running related injury, 15 (71%) runners in the functional strength training group, 11 (68%) runners in the resistance strength training group and 7 (46%) runners in the stretching control group had reported a previous lower extremity injury at some point in their life. Baseline anthropometric measures as well as running exposure characteristics for the injured and non-injured participants in each training group are presented in Table 3.

Four participants of 52 (8%) reported more than one running related injury: two functional strength training group participants, one resistance strength training group participant and one stretching control group participants. The resistance strength training group ran a mean of 12.5 h (total = 538.5 h) during the 6-month follow-up period, while runners in the functional strength training ran a mean of 16.3 h (total = 699.4 h) and the stretching control group ran a mean of 14 h (total = 600.3 h). The running IR was 31.6 injuries/1000 running hours (95% CI; 18.4, 50.5) for the resistance strength training group, 32.9 (95% CI; 20.8, 49.3) for the functional strength training group, and 26.7 (95% CI; 15.2, 43.2) for the control group. Weekly severity scores for the most severe injury of each participant who reported a running related injury can be seen in Fig. 3.

Of the 96 participants that completed at least three training sessions on average per week as instructed (per protocol analysis: resistance = 36, functional = 32, control = 28), 43 participants (45%) reported at least one running-related injury. For the resistance training group, 14 participants (36%) reported at least one running-related injury. For the functional training group, 16 participants (50%) reported at least one related injury and for the stretching group 12 participants (43%) reported at

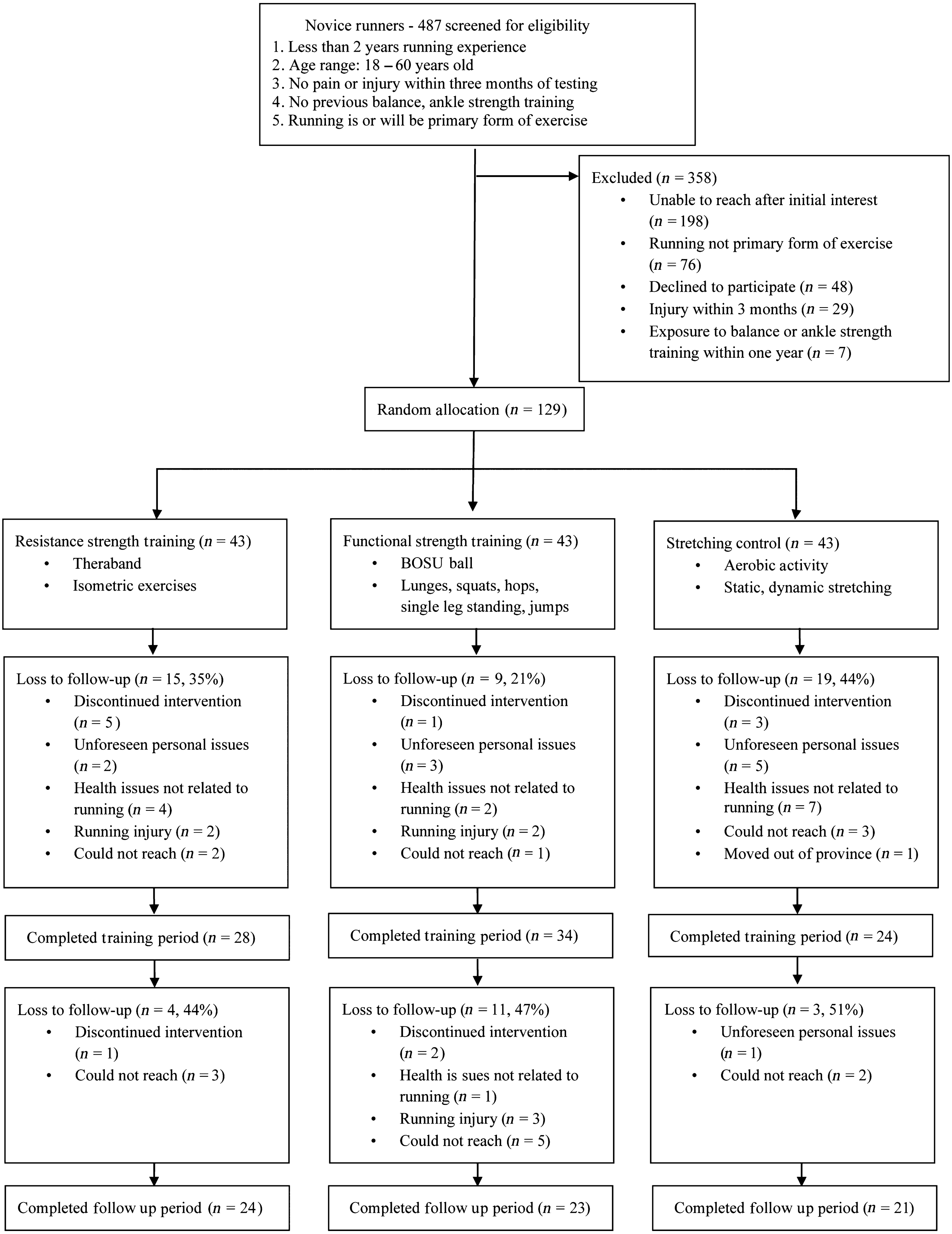

Fig. 2. Flow of participants through the study protocol.

least one running related injury. One participant in the resistance training group and one participant in the functional training group reported two running related injuries. The resistance training group ran a total of 506 h while the functional training ran a total of 672 h and the control group ran a total of

Table 2. Baseline anthropometric and running history characteristics

Characteristic	Functional strength training		Resistance strength training		Stretching control	
	Completed (*n* = 23, 53%)	Drop out (*n* = 20, 47%)	Completed (*n* = 24, 56%)	Drop out (*n* = 19, 44%)	Completed (*n* = 21, 49%)	Drop out (*n* = 22, 51%)
Ge nder (*n* female, %)	21 (91)	13 (65)	16 (67)	17 (89)	17 (81)	19 (86)
Age (years; median, range)	33 (22, 54)	32 (20, 57)	30 (18, 50)	37 (19, 50)	31 (18, 59)	34 (18, 50)
Height (cm; median, range)	165 (148, 182)	169 (156, 182)	167 (155, 189)	163 (156, 181)	166 (150, 181)	165 (153, 182)
Mass (kg; median, range)	66 (49, 99)	78 (56, 102)	75 (51, 150)	74 (57, 95)	70 (56, 110)	79 (49, 106)
Running experience (weeks; median, range)	8 (0, 104)	6 (0, 104)	1 (0, 64)	0 (0, 32)	10 (0, 104)	3 (0, 77)
Frequency of runs per week (median, range)	2 (0, 4)	2 (0, 4)	1 (0, 4)	0 (0, 4)	2 (0, 5)	1 (0, 3)
Weekly distance (km; median, range)	8 (0, 25)	4 (0, 15)	4 (0, 18)	0 (0, 25)	10 (0, 35)	2 (0, 20)
Training session duration (minutes; median, range)	30 (0, 60)	20 (0, 60)	18 (0, 40)	0 (0, 30)	25 (0, 45)	20 (0, 45)
Previous injuries (*n*, %)	12 (52)	13 (65)	14 (58)	11 (58)	10 (48)	11 (50)
Primary training surface (*n*, %)						
Pavement	9 (39)	4 (20)	8 (33)	6 (32)	4 (19)	11 (50)
Trail	1 (4)	2 (10)	0	0	0	0
Treadmill	10 (44)	11 (55)	12 (50)	9 (47)	15 (71)	10 (45)
Indoor Track	3 (13)	3 (15)	4 (17)	4 (21)	2 (10)	1 (5)
Pairs of running footwear (*n*, %)						
12	11 (48)	11 (55)	14 (58)	13 (68)	12 (57)	16 (73)
3	10 (43)	7 (35)	10 (42)	6 (32)	8 (38)	5 (22)
>3	0	1 (5)	0	0	0	1 (5)
Frequency of replacing footwear (*n*, %)						
6–12 months	15 (65)	10 (50)	10 (42)	11 (58)	12 (57)	16 (73)
13–24 months	5 (22)	6 (30)	10 (42)	4 (21)	5 (24)	2 (9)
>24 months	3 (13)	4 (20)	4 (16)	4 (21)	4 (19)	4 (18)

Table 3. Running exposure and baseline anthropometric characteristics for the injured and non-injured participants in each training group

Characteristic	Functional strength training		Resistance strength training		Stretching control	
	Injured, *n* = 21, 49%	Non-injured, *n* = 22, 51%	Injured, *n* = 16, 37%	Non-injured, *n* = 27, 63%	Injured, *n* = 15, 35%	Non-injured, *n* = 28, 65%
Gender (*n* female, %)	19 (90)	15 (68)	12 (75)	21 (78)	11 (73)	25 (89)
Age (years; median, range)	33 (22, 57)	33 (20, 54)	32 (18, 50)	31 (19, 50)	36 (18, 54)	33 (18, 59)
Height (cm; median, range)	166 (156, 182)	166 (148, 182)	166 (159, 189)	167 (155, 184)	162 (150, 181)	167 (154, 182)
Mass (kg; median, range)	70 (49, 102)	73 (50, 98)	75 (58, 131)	74 (51, 150)	82 (56, 110)	74 (49, 106)
Baseline running experience (weeks; median, range)	12 (0, 104)	3 (0, 104)	4 (0, 24)	0 (0, 64)	10 (0, 520	6 (0, 104)
Previous injuries (n, %)	15 (71)	10 (45)	11 (68)	13 (48)	7 (460	14 (50)
Total running exposure (hours; median, range)	10.1 (1.4, 47.5)	18.1 (0, 50.3)	14.6 (0.7, 49.1)	8.1 (0, 31.2)	12.9 (0.6, 51.9)	6.9 (0, 58.9)
Weekly running exposure (minutes; median, range)	55 (32, 119)	54 (0, 132)	51 (25, 131)	51 (0, 140)	85 (28, 130)	45 (0, 297)
Total running exposure before injury (hours; median, range)	3 (1, 38)	NA	5 (1, 15)	NA	4 (1, 15)	NA
First appearance of injury (week; median, range)	5 (1, 21)	NA	5 (1, 18)	NA	4 (1, 9)	NA

536 h. The running IR was 27.7/1000 running hours (95% CI; 15.1, 46.5) for the resistance training group, 25.3 (95% CI; 14.7, 40.5) for the functional training group and 22.4 (95% CI; 11.6, 39.2) for the control group.

Knee injuries made up the majority of running related injuries across all three intervention groups (46%, 26 of the 56 reported injuries). The ankle was the next most commonly injured location (20%, 11 of the 56 reported injuries), followed by the foot (11%, 6 of the 56 reported injuries). Table 4 details the number of running related injuries, the mean severity score, and the prevalence of time loss injuries at each anatomical location for each group. The mean weekly severity of running related injuries was similar across the three intervention groups [100

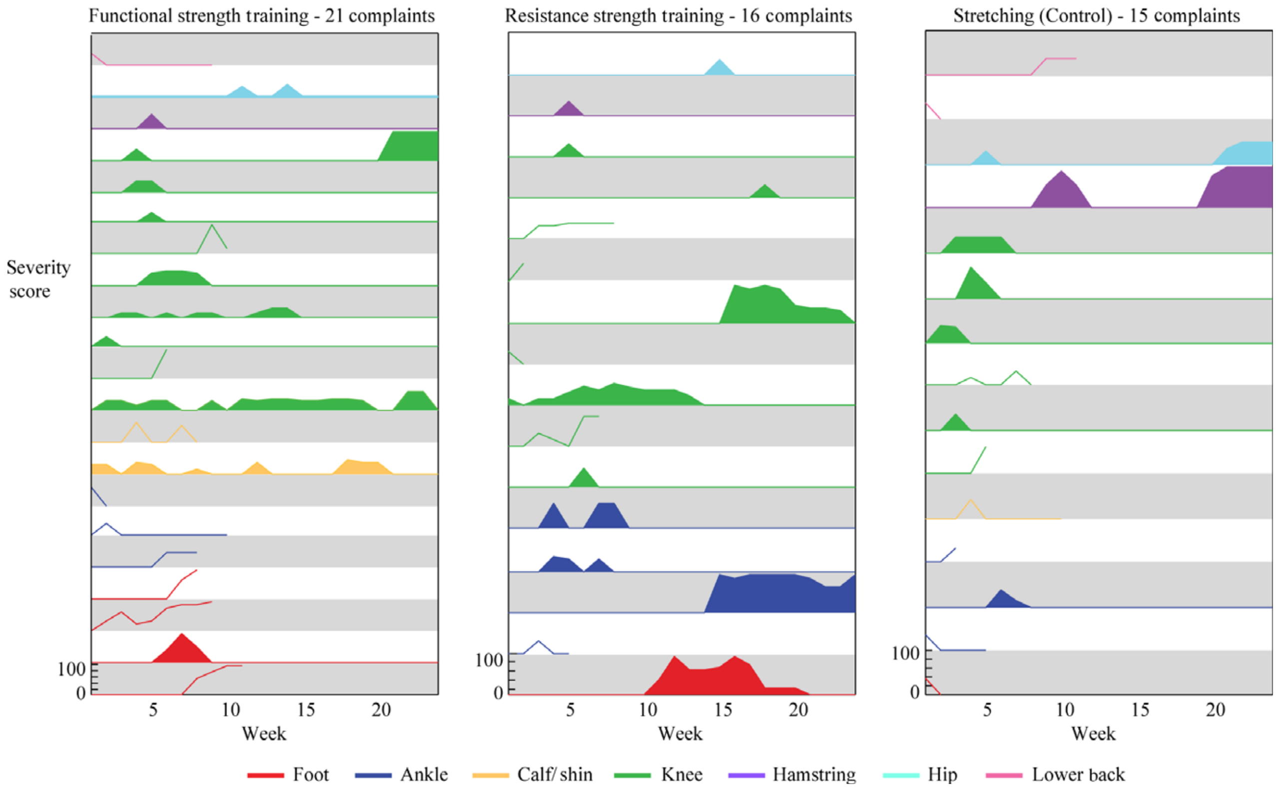

Fig. 3. Weekly severity scores for the most severe injury reported by each participant during the 6-month follow-up period. Severity scores ranged from zero (no complaint) to 100 (time loss with severe pain). Each gray and white box represents the severity score for a single participant as a function of time. Participants who completed the entire 6-month follow-up period are shaded while participants who dropped out are represented as lines.

point scale: median, range; functional strength training 43.0 (31.0, 92.0); resistance strength training 37.7 (31.0, 84.4); stretching control 37 (31.0, 78.1)]. Of the 56 running related injuries, 10 required moderate or major reductions in running duration and/or distance: three participants in the functional strength training group, three participants in the resistance strength training group and four participants in the stretching control group. Twelve participants required full time loss from running for at least 1 week: seven participants in the functional strength training group, four in the resistance strength training group and one in the stretching control group. Time loss injuries that underwent clinical assessment by a physiotherapists included the following: Foot – midfoot sprain, peroneus longus tendinitis (2), plantar fasciitis, bony projection irritation; Ankle - Achilles tendinopathy; Knee – tibiofibular ligament sprain, anterior cruciate ligament sprain, patellofemoral pain syndrome (2), medial knee joint line pain; Upper leg – hamstring muscle strain.

The number of new running related injuries and the total running exposure hours for each month of the 6-month follow-up period are presented in Table 5. All training groups experienced the majority of running related injuries during the 8-week training period. For the functional strength training group, 83% (19 of 23) of the running related injuries first appeared during the 8-week training period. For the resistance training group, 65% (11 of 17) of the running related injuries first appeared during the 8 week training period and 88% (14 of 16) of the running related injuries in the stretching control group appeared during the first 8 weeks of the study.

Discussion

The purpose of this RCT was to explore the incidence of injury in novice runners enrolled in a resistance strength training program, a functional strength training program, or a stretching control program. It was speculated that this exploratory study would provide useful information for future RCTs regarding the risk of injury and dropout rates accompanying home based exercise interventions geared towards novice runners. This discussion will focus on four main findings from this study: (1) There was no difference between study groups on running injury rates; (2) injury rates in the current study are relatively high, highlighting the utility of using a weekly overuse injury surveillance questionnaire; (3) injury rates were higher during the 8 week

Table 4. Anatomical distribution of running related injuries

	Functional strength training			Resistance strength training			Stretching control		
	Injury rate (/1000 h)	Time loss (*n*)	Average weekly severity score (median, range)	Injury rate (/1000 h)	Time loss (*n*)	Average weekly severity score (median, range)	Injury rate (/1000 h)	Time loss (*n*)	Average weekly severity score (median, range)
Total	32.9	7	43 (31, 92)	31.6	4	38 (31, 84)	26.7	1	37 (31, 78)
Foot	5.7	4	69 (61, 77)	1.9	1	68.5	1.7	0	37
Ankle	4.3	0	46 (37, 60)	7.4	1	47 (31, 84)	6.6	0	35 (31, 40)
Lower leg	2.8	0	47 (36, 58)	0	0	0	1.7	0	44
Knee	15.7	3	49 (31, 92)	16.7	2	38 (31, 62)	10.0	0	38 (31, 60)
Upper leg	1.4	0	46	1.9	0	35	1.7	1	78.1
Hip	1.4	0	34	1.9	0	37	1.7	0	44.2
Lower back	1.4	0	37	1.9	0	37	3.3	0	37 (37, 37)

Table 5. Frequency of new running related injuries, running exposure hours and injury incidence rate (no. injuries per 1000 h of exposure) for each month of the 6-month follow-up

	Functional strength training			Resistance strength training			Stretching control		
	Running related injuries (*n*)	Running exposure (h)	Injury rate (*n*/1000 h)	Running related injuries (*n*)	Running exposure (h)	Injury rate (*n*/1000 h)	Running related injuries (*n*)	Running exposure (h)	Injury rate (*n*/1000 h)
Weeks 1–4	10	165.3	60.4	7	140.8	49.7	10	149.1	67.1
Weeks 5–8	9	141.9	63.4	4	102.9	38.9	4	106.4	37.6
Weeks 9–12	2	92.9	21.5	1	86.5	11.6	2	93.7	21.4
Weeks 13–16	0	105.8	0.0	3	65.7	45.6	0	83.8	0.0
Weeks 17–20	0	85.2	0.0	1	76.8	13.0	0	93.4	0.0
Weeks 21–24	2	108.5	19.4	1	65.8	15.2	0	74.0	0.0
Total	23	699.4	30.0	17	538.5	29.7	16	600.3	25.0

training period compared to the 4 month maintenance period for all three groups.

While the sample size was small, leading to the risk of type II error, the injury rates were similar between the three training groups for the 6-month tracking period. Due to the lack of power, this study cannot definitively determine the effectiveness of either strengthening intervention. The results from this study can be used to accurately power a larger RCT to effectively evaluate the influence of these training interventions on injury risk. The sample size for this RCT was determined based on the assumption of a 20% drop out rate. The dropout rates for the full 6-month follow-up period were approximately 50% across all three training interventions. Previous studies reported dropout rates between 10% and 20% (van Mechelen et al., 1993; Buist et al., 2008; Bredeweg et al., 2012). However, previous intervention studies recruited runners that were currently enrolled in a start-to-run program (Buist et al., 2008; Bredeweg et al., 2012). The runners in the current study were not a part of any organized running group. Therefore, they may have lost motivation to run more easily without the incentive of an organized running group. Future RCTs evaluating a home-based training intervention for runners that are not involved in an organized running group should develop strategies to reduce the risk of participant dropout. This may include more contact with study coordinators or organized group training and running sessions. If this support is not available, future studies should adjust their sample size calculation for a larger dropout rate.

The higher than average loss to follow-up rates in the current study may be due to a variety of reasons, including the lack of belief that the given training intervention will help, the ease of the training program or the lack of enjoyment that comes from participating in the training. The lack of enjoyment for the stretching intervention may be of particular interest. The stretching exercises did not change over the course of the 8 week training period, whereas the resistance and functional strength training exercises became progressively more difficult every 2 weeks. This monotonous structure may not have been stimulating enough to maintain the interest of the participant. Future research that incorporates a stretching control group should consider changing the stretching exercises every 2 weeks to try to increase the interest of the participant. An objective questionnaire provided to dropout participants would also elucidate more details regarding their choice to leave the study.

For the current study, running injury rates ranged between 25 and 30 injuries per 1000 h of running exposure. Previous studies have reported injury rates in novice runners ranging from 8.9 (95% CI 7.6, 10.3) to 33.0 (95% CI 27.0, 40.0) injuries per 1000 h of running exposure (Bovens et al., 1989; Buist et al., 2008). A recent meta-analysis estimated running injury rates for novice runners to be 17.8 (95% CI 16.7, 19.1) injuries per 1000 h of running exposure based on past studies (Videbæk et al., 2015). The injury rates for the current study are at the upper end of the range of previously reported injury rates for novice runners. This finding may partially be a result of the nature of the injury definition and the overuse injury questionnaire used to identify running injuries. Only 12 participants (23%) that sustained a running related injury in the current study required time loss from running. The remaining participants reported reductions in running exposure due to their injury, but did not have to stop running all together. Therefore, a large portion of running related complaints would not have been captured if a time loss injury definition had been used to track novice runners. Future studies investigating injury incidence in novice runners should consider using an overuse injury questionnaire to capture a more inclusive representation of the injury burden.

The current findings also support the potential need for a pre-conditioning period when training novice runners. The results from this pilot investigation indicate that all three training groups had the highest incidence of injury during the first 8 weeks of the study during the training period compared to the 4 month maintenance period after the training. It should be noted that this could be a result of reporting bias since running injuries were self-reported and only the time loss injuries were clinically evaluated by a physiotherapist. When considering the injury location, complaints at the foot had some of the highest average severity scores. A tissue will positively remodel and strengthen in response to an external load, as long as enough recovery time is provided (Kjaer, 2004). If the recovery time is not sufficient or the external load is too high, an overuse injury may occur (Hreljac, 2004). As novice runners tend to be inactive prior to commencing a regular running routine (Buist et al., 2010), the combination of regular running in addition to exercise training may have overloaded the tissues in the foot. It may have been more beneficial to begin the exercise training intervention prior to commencing a regular running routine. However, a previous RCT found that participation in a preconditioning program incorporating walking and hopping exercises prior to commencing a running program did not influence the incidence of injury in a group of novice runners (Bredeweg et al., 2012). This preconditioning program, however, was only 4 weeks in duration. Therefore, it could be that a longer preconditioning period (8 weeks) prior to commencement of a running program may be more beneficial than starting both the running routine and the exercise intervention at the same time.

One of the strengths of this investigation includes the rigorous RCT methodology. In addition, the inclusion of running exposure on a weekly basis informed the estimation of injury rates rather than depending purely on injury incidence proportions. This is also the first study to evaluate injury risk associated with home-based strength training interventions for novice runners. Certain limitations exist for this study. First and foremost the small sample size is a limitation. While this was intended to be a pilot RCT for injury risk evaluation, the high dropout rate was unanticipated and further reduced the sample size. A larger sample would have allowed for the initial goal of using a more comprehensive statistical analysis (multivariate regression analysis), which could have included controlling for potential confounders such as previous injury and running experience at baseline (Baltich et al., 2014). If the intervention groups should lead to a 50% reduction in the injury incidence and assuming the control group has an injury incidence of 40% (per 100 runners), 82 subjects would be needed in each group in order to achieve 80% statistical power with an $\alpha = 0.05$. Accounting for a 50% drop out rate would require 164 participants in each group for future larger scale RCTs. The loss to follow-up may have also resulted in selection bias. Another limitation is the limited staff resources available for this RCT. The use of more research staff may have allowed for more frequent direct contact with the participants to increase motivation and training participation for new runners. Additionally, only the time loss injuries were clinically evaluated by a physiotherapist. All other physical complaints were self-reported by participants. This cohort of runners was also primarily female, making the generalizability to males difficult. Finally, a longer follow-up period of up to one year may have been informative regarding long-term injury incidence.

Perspectives

The results of this pilot study suggest that the injury incidence proportion and injury rate are similar for novice runners enrolled in a resistance strength training program, a functional strength training program, or a stretching program. Dropout rates of approximately 50% in the current study are higher than previously reported dropout rates for participants enrolled in a supervised running group. Of the 52 participants who reported running related injuries, only 12 injuries lead to time loss from running, supporting the use of an overuse questionnaire to report all injuries rather than a time loss definition. The majority of running related injuries were reported during the first 8 weeks of the 6-month follow-up period. The purpose of this pilot RCT was to gain knowledge for a future larger-scale RCT evaluating home-based strength training for novice runner injury prevention. The results of this study bring into the question the practicality of executing a larger-scale study with the same design. The high drop-out rates in combination with the high yet similar injury rates between groups would promote adjustments to the study design. Future research should consider implementing the strength training interventions as a pre-conditioning program prior to commencing a regular running routine. Additionally, different methods to promote participant retention should be considered for novice runners enrolled in a home-based exercise intervention. Alternatively, the use of supervised training may increase adherence to the training, reduce drop-out rates, and improve the potential for injury reduction. Future results from this RCT will include the influence of training on strength, running mechanics and balance in novice runners.

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