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Health and economic burden of running-related injuries in runners training for an event: A prospective cohort study

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Prospective running-related injury (RRI) data from runners training for an event are scarce, especially with regard to RRI-associated costs. Therefore, the aim of this study was to investigate the prevalence and economic burden of RRIs in runners participating in an organized training program preparing them for an event. This was a prospective cohort study with 18 weeks of follow-up. Individuals aged 18 or older and registered to participate in an organized running program were eligible. Follow-up surveys were sent every 2 weeks to collect data about running exposure, RRIs, and costs. Of the 161 potential participants, 53 (32.9%) were included in this study. A total of 32 participants reported 41 RRIs. The mean prevalence during follow-up was 30.8% [95% confidence interval (CI) 25.6–36.0%]. Overuse was the main mechanism of RRI (85.4%, *n* = 35). An RRI was estimated to have an economic burden of €57.97 (95% CI €26.17–94.00) due to healthcare utilization (direct costs) and €115.75 (95% CI €10.37–253.73) due to absenteeism from paid work (indirect costs). These results indicate that the health and economic burden of RRIs may be considered significant for public health. Therefore, prevention programs are needed for runners participating in organized training programs.

Physical activity is associated with reduced all-cause mortality and disability (Chakravarty et al., 2008; Samitz et al., 2011). However, the pandemic of physical inactivity is worrisome worldwide, and efforts to reduce its burden should be considered a public health priority (Hallal et al., 2012; Kohl et al., 2012). Running is popular among individuals seeking an active and healthier lifestyle (Stamatakis & Chaudhury, 2008; Ottesen et al., 2010). It has been estimated that about 6% of the English population practiced running (more than once a week) (Stamatakis & Chaudhury, 2008), and according to the 'Nederlands Olympisch Comité * Nederlandse Sport Federatie' (NOC*NSF), 7% of the Dutch population was found interested in starting to run in 2013 (NOC*NSF, 2014).

One effective way to engage individuals in running is to promote organized running training toward a specific event (Ooms et al., 2013). Running programs are designed to increase participation in running and to prevent running-related injuries (RRIs). These programs primarily attract novice runners seeking to complete a particular distance, or amateur (non-elite) runners who seek to complete a longer distance or set a personal time record. Therefore, such training programs are inherently different to other running programs, because there is a diverse mixture of participants with different fitness levels, experience, and goals.

RRIs have been described as an important barrier to compliance with running practice (Koplan et al., 1995). These injuries can result in health and economic burden such as physical complaints (usually chronic with symptomatic long periods until recovery; Nielsen et al., 2014), healthcare utilization, and absenteeism from work (Kluitenberg et al., 2013). The consequences of RRIs for the individual runner and society claim the necessity of preventive efforts for running programs. In addition to injury rates and clinical consequences, an insightful approach to show the extent to which RRIs impact the individual and society is to report the economic consequences of such injuries (van Mechelen et al., 1992). Cost analysis of RRIs may influence the allocation of financial resources to support prevention programs. However, to the best of our knowledge the economic burden of RRIs is unknown.

The importance of understanding health and economic burden of sports injuries for the development of preventive interventions has been well recognized (van Mechelen et al., 1992). However, prospective injury data from runners participating in organized programs to train for an event are scarce (Buist et al., 2010; Verhagen, 2012). This hampers the development of effective preventive strategies focused on this population. This is noteworthy as available data suggest that inexperienced runners are at increased risk of injuries when compared with experienced runners (Videbaek et al., 2015). Therefore, the aim of this study was to investigate the health and economic burden of RRIs in runners participating in an organized training program preparing them for a specific event.

Methods

Design and participants

This was a prospective cohort study carried out during running clinics organized by the Tilburg Ten Miles (TTM), between April 2014 and September 2014. The TTM is an annual single-day running event in Tilburg, The Netherlands, consisting of three possible distances (5 or 10 km or 10 miles). The event is accessible for all levels of runners and in 2014 attracted over 10 000 runners. In 2005, Haile Gebrselassie set the current standing 10-mile world record at 44.42 min at this event.

Within the TTM clinics, participants are offered an organized training program available for all who have registered to participate in one of the TTM distances. Individuals were eligible for participation in this study if they were 18 years or older, and if they were registered to participate in the TTM clinics. At the first supervised training session, invitation cards were distributed among the participants of the TTM clinics, and the aims of the study and procedures were explained. The invitation card contained a quick response code and the URL of the study website. The participants were invited to visit the study website, where a detailed explanation on the study background and procedures was provided. In the website, they could also register to partake in the study. Injured participants at baseline were not excluded from the study, because it has been recommended that studies investigating the overall burden of sports injuries (i.e., including overuse injuries) should preferably report the results in prevalence repeatedly measured over time instead of incidence (Bahr, 2009; Clarsen et al., 2013). Informed consent was obtained from all the participants and the study was approved by the medical ethics committee of the VU University Medical Center, Amsterdam, The Netherlands.

Running program (TTM clinics)

At the start of the TTM clinics, the participants received a booklet with instructions and information about the running program, containing a complete description of the methods and goals of all supervised and unsupervised training sessions. Once a week, supervised training sessions were conducted in groups, coordinated by a certified trainer who accompanied the group during these sessions. The participants were instructed to follow the booklet recommendations during the two weekly unsupervised training sessions.

Each supervised training session lasted on average 1.5 h: 20 min of warm-up, 60 min of running training, and 10 min of cool down. The warm-up was composed of 5 min of jogging, 10 min of stretching, and 5 min of jogging again, and the cool down was composed of 10 min of stretching. The aims of the supervised training sessions were to achieve approximately 5 km of running and to focus on speed. For the two weekly unsupervised sessions, endurance and interval training was advised. The running volume focused on the distance of the TTM event that the participants were registered for.

The running intensity was individualized by running experience and speed. In the first running session, the participants were divided in two groups: beginners and experienced runners. The experienced runners were tested during a 1-km run, and they were further divided in groups according to their speed. The groups were composed by 15–20 participants and a running trainer was assigned for each group. Trainers were responsible for the running dosage and individual evaluation of their own group. During the TTM clinics, participants could change groups according to their running performance. If necessary, trainers provided additional and individualized recommendations to better tailor the running training for each participant.

Data collection procedure

After giving the online informed consent, a link to an online baseline questionnaire was sent by e-mail to the participants. This questionnaire asked about demographics, running experience, participation in other sports, current medical conditions, previous (last 12 months) RRIs, and current RRIs. Online follow-up questionnaires were completed every fortnight. The aim of this questionnaire was to collect data about the participants' running exposure and to record any health problems experienced in the preceding 2 weeks. In case of a sustained RRI, healthcare utilization and missing days from paid work due to the RRI were also registered. If no response was received within 1 week, a reminder was sent by e-mail urging the participant to complete the follow-up questionnaire. Baseline and follow-up questionnaires were developed in Polldaddy at https://polldaddy.com.

Health problem registration

In order to prospectively register the health problems during the follow-up, a Dutch version of the Oslo Sports Trauma Research Centre (OSTRC) Questionnaire on Health Problems (Clarsen et al., 2014) was used in the follow-up questionnaires. The OSTRC questionnaire has been translated previously and has been adapted to the Dutch language (Pluim et al., 2015). The questionnaire starts by asking all injured participants four key questions on: (a) the extent to which injury, illness, or other health problems has affected running participation; (b) training volume; (c) running performance; and (d) the extent to which they have experienced symptoms during the previous 2 weeks. If no problems were reported regarding these four key questions, the questionnaire was finished. However, if a problem was reported on any of the four key questions, the participant was asked to specify whether the problem was an illness or an injury. In case of an illness, the questionnaire was finished.

In the case of an injury, participants were asked to report the anatomical location, the injury type, a description of the symptoms and onset, the number of days of time loss (defined as the number of running training sessions not fully accomplished, or completely missed due to RRIs), and whether or not the injury was running related. In the case of multiple injuries during a particular fortnight, they were asked to register the injury that had caused most complaints. If any, additional injuries (those that had not caused most complaints during a particular fortnight) could be reported separately. Participants were instructed to report all problems, regardless of whether they had already reported the same one in previous biweekly periods.

Health problem classification

All health problems reported were analyzed in order to confirm if they were illnesses or injuries. Health problems were classified as injuries if they were "disorders of the musculoskeletal system, or concussions," and were classified as illnesses if they "involved other body systems," such as (but not limited to) the respiratory, cardiovascular, or digestive systems (Clarsen et al., 2014). Injuries were classified as RRIs when they were sustained during participation in running training or during a running event.

RRIs were further subcategorized into acute (i.e., the onset could be linked to a specific injury event) or overuse injuries (i.e., any injury that could not be linked to a clearly identifiable event) (Clarsen et al., 2014). The Orchard Sports Injury Classification System v.10 (Rae & Orchard, 2007) was used to provide a specific classification for each RRI. Substantial health problems were defined as those leading to moderate or severe reductions in training volume, moderate or severe reductions in running performance, or complete inability to run (Clarsen et al., 2014).

Economic consequences of RRIs

Participants who reported RRIs were asked about their healthcare utilization (direct costs) and missing days from paid work (indirect costs) due to RRIs for the duration of their reporting of symptoms. Table 1 provides the cost categories that were registered and the related costs used in this evaluation. Dutch-standardized prices were used to value healthcare utilization (van Roijen et al., 2010). Costs of absenteeism from paid work were estimated based on the mean income (van Roijen et al., 2010) and the mean working hours (Centraal Bureau voor de Statistiek, 2014) of the Dutch population according to age and gender.

Data analysis

Descriptive analyses were performed to present baseline and follow-up data. Percentages were calculated for categorical variables. Mean and its 95% confidence interval (95% CI) were calculated for the continuous data with Gaussian distribution; otherwise, the median and the 25–75% interquartile range (IQR) were calculated.

Prevalence calculations

Prevalence calculations followed the methodology outlined by Clarsen et al. (2014). For each biweekly follow-up period, prevalence measures were calculated for the reported problems by dividing the number of participants reporting a problem by the total number of questionnaire respondents. Thereafter, the mean prevalence with its 95% CI was calculated.

Cumulative prevalence was also calculated by dividing the number of participants that had reported RRIs during the entire follow-up by the number of participants enrolled in the study. Recurrent RRIs were classified according to the methods proposed by Fuller et al. (2007), using healthcare professional (LCHJ) opinion rather than return to play to determine complete recovery. Prevalence analyses were conducted in Microsoft® Excel® version 14.4.9 (Microsoft Corporation, Redmond, WA, USA).

Table 1. Costs applied in the economic analysis

Description	Cost, €
Healthcare costs (direct costs)	
General practitioner (per visit, 10 min)	28.00
General practitioner (home visit)	43.00
Medical specialist (per visit)	72.00
Physiotherapist (per visit)	36.00
Costs of productivity loss (indirect costs)	
Absenteeism from paid work (per hour)*	30.02 (9.27–36.41)

Prices according to the Dutch Health Insurance Board (College voor Zorgverzekeringen) (van Roijen et al., 2010).

*Indirect costs for paid work were estimated based on the mean income (van Roijen et al., 2010) and the mean working hours (Centraal Bureau voor de Statistiek, 2014) of the Dutch population according to age and gender. The value for paid work in this table is the mean price followed by the minimum and maximal values and do not represent the actual values used in calculations, because those were conducted according to standardized prices by age and gender.

Severity

In order to monitor the progress of the RRIs over time, a severity score ranging from 0 to 100 was calculated for all reported RRIs based on the four questions of the OSTRC questionnaire (Clarsen et al., 2014). The cumulative severity score was calculated as an estimation of the total impact that each RRI had over the course of the project. The cumulative time loss was also calculated for each RRI by summing the weekly reported time loss. For all calculations, recurrent RRIs were defined as those with the same location and type as the index injury, even if they were re-injuries (after full recovery) or exacerbations of a not fully recovered injury (Fuller et al., 2007). The results were expressed as median and 25–75% IQR. Severity analyses were conducted in Microsoft® Excel® version 14.4.9 (Microsoft Corporation, Redmond, WA, USA).

Costs

Mean direct, indirect, and total RRI costs were estimated per injury and per participant (considering the entire cohort, regardless of injury status). Differences in costs for overuse and acute RRIs, and also for males and females, were calculated. For the cost analysis, the 32 unique RRIs that were not present at baseline were considered because it was not possible to estimate the costs of RRIs that had occurred before the follow-up. As the costs data are non-parametric, 95% CIs were obtained by bootstrapping the data with 2000 replications (Efron & Tibshirani, 1986; Efron, 1987; Chaudhary & Stearns, 1996). Cost analyses were conducted in IBM® SPSS® version 22.0 (IBM Corporation, Armonk, NY, USA).

Results

Research population and response rate

Figure 1 describes the flow of the participants during the study. A total of 161 runners participated in the TTM clinics in 2014. Of the total, 53 participants (32.9%) enrolled in the study. The follow-up of the study was 18 weeks; however, the participants were enrolled in the study at different time points. The average response rate to the follow-up questionnaires was 73.1% (95% CI 62.5–83.7%), and there were two dropouts between the second and the third biweekly period. The characteristics of the participants are summarized in Table 2. Apart from body height and weight, there were no significant differences between men ($n = 22$, 41.5%) and women ($n = 31$, 58.5%).

Running exposure

The cumulative hours of running exposure were 1215 (1138 h during training and 77 h during running events),

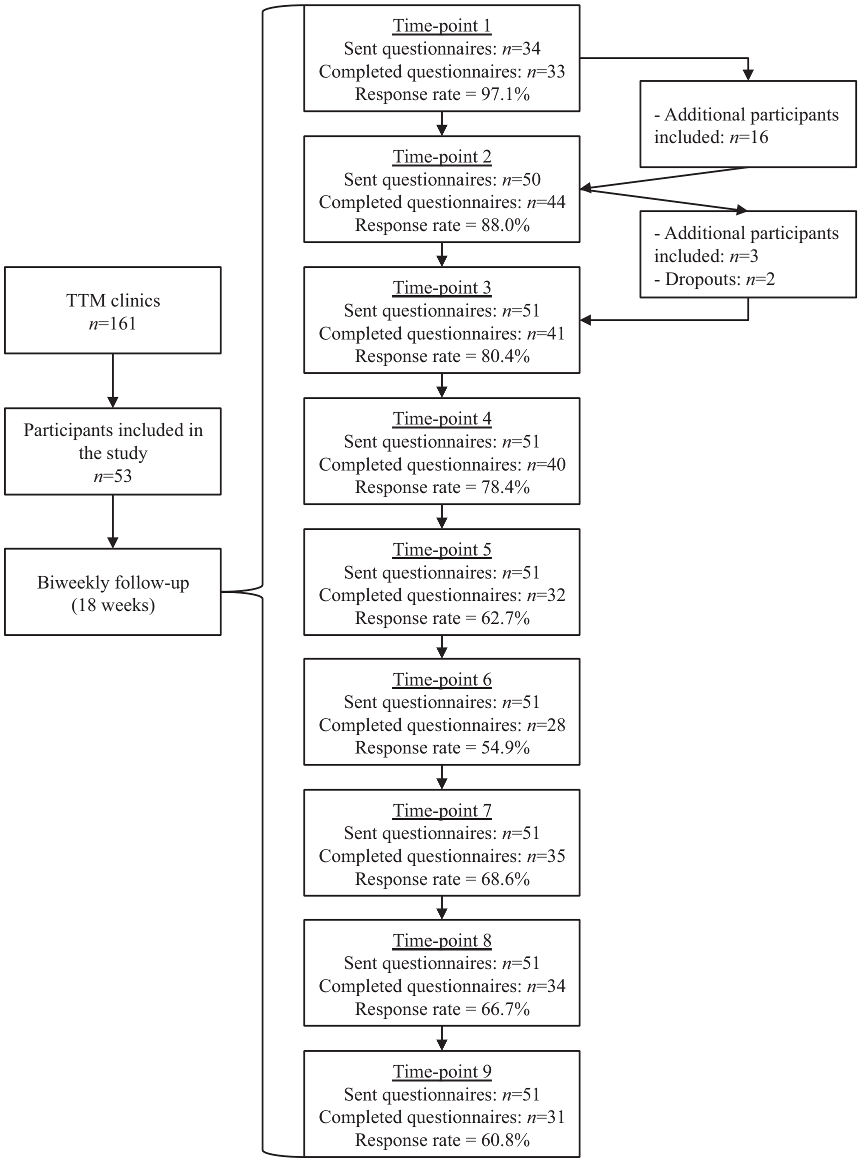

Fig. 1. Flow of the participants during the study. TTM, Tilburg Ten Miles.

with a median of 1.8 h per week (IQR 1.0–2.5). In total, 9365 km of running was recorded (8462 km during training and 903 during running events), with a median of 14.8 km per week (IQR 7.5–20.0). A total of 1204 running sessions was recorded (1148 running training sessions and 56 running events), with a median of 2.0 sessions per participant per week (IQR 1.0–2.5).

Prevalence, severity, and nature of RRIs

During the follow-up 41 RRIs were reported by 32 participants. Seven participants reported multiple RRIs. The mean prevalence of RRI during follow-up was 30.8% (95% CI 25.6–36.0%), and the cumulative prevalence was 60.4% ($n = 32$). The mean prevalence of RRI was higher for males (mean of 19.3%, 95% CI 15.8–22.8%) than for females (mean of 11.5%, 95% CI 8.1–14.8%), with a mean difference of 7.8% (95% CI 3.0–12.6%). The mean prevalence of RRIs for participants who reported up to 1 year of running experience was 27.7% (95% CI 22.1–33.3%), and for those who reported more than 1 year of running experience was 34.2% (95% CI 25.2–43.1%), with a mean difference of 6.5% (95% CI −3.2% to 16.2%).

The average and cumulative severity scores were 39.5 (IQR 22.0–68.0) and 79.0 (IQR 28.0–175.0), respectively. A total of 53.7% ($n = 22$) of the RRIs was classified as substantial. The absolute number, prevalence, and severity measures of the RRIs reported during follow-up are described in Table 3. In total, 26.8% ($n = 11$) of the RRIs had caused no time loss, 65.9% ($n = 27$) did not require medical attention, and 24.4% ($n = 10$) had neither caused time loss nor required medical attention.

A total of 35 overuse RRIs (85.4%) was reported by 29 participants, and six acute injuries (14.6%) were

Table 2. Characteristics of the participants

	All participants *n* = 53	Men *n* = 22	Women *n* = 31
Age, years	44.1 (41.3–47.0)	44.0 (39.1–48.9)	44.2 (40.5–47.9)
Height, cm	174.0 (171.4–176.5)	181.2 (177.8–184.5)	168.9 (166.5–171.2)
Weight, kg	73.5 (69.9–77.0)	82.6 (77.4–87.8)	67.0 (63.6–70.3)
BMI, kg/m^2	24.2 (23.3–25.0)	25.1 (23.9–26.4)	23.5 (22.4–24.6)
Running experience, *n* (%)			
No experience	16 (30.2%)	8 (36.4%)	8 (25.8%)
Up to 1 year	14 (26.4%)	7 (31.8%)	7 (22.6%)
1–5 years	16 (30.2%)	4 (18.2%)	12 (38.7%)
More than 5 years	7 (13.2%)	3 (13.6%)	4 (12.9%)
Practice of other sports, *n* (%)			
Yes	32 (60.4%)	14 (63.6%)	18 (58.1%)
No	21 (39.6%)	8 (36.4%)	13 (41.9%)
Chronic condition, *n* (%)			
Yes	9 (17.0%)	5 (22.7%)	4 (12.9%)
No	44 (83.0%)	17 (77.3%)	27 (87.1%)
Medication, *n* (%)			
Yes	10 (18.9%)	3 (13.6%)	7 (22.6%)
No	43 (81.1%)	19 (86.4%)	24 (77.4%)
Current RRI, *n* (%)			
Yes	14 (26.4%)	7 (31.8%)	7 (22.6%)
No	39 (73.6%)	15 (68.2%)	24 (77.4%)
Previous RRI (last 12 months), *n* (%)			
Yes	15 (28.3%)	8 (36.4%)	7 (22.6%)
No	38 (71.7%)	14 (63.6%)	24 (77.4%)
TTM event			
First tertile of finish time*	9 (17.0%)	3 (13.6%)	6 (19.4%)
Second tertile of finish time*	7 (13.2%)	2 (9.1%)	5 (16.1%)
Third tertile of finish time*	9 (17.0%)	2 (9.1%)	7 (22.6%)
Not able to finish	3 (5.7%)	2 (28.6%)	1 (3.2%)
No participation	11 (20.8%)	6 (27.3%)	5 (16.1%)
No response	14 (26.4%)	7 (31.8%)	7 (22.6%)

All characteristics were collected at baseline, except for the TTM event data. Continuous data are given as mean and its 95% confidence interval (95% CI).
*Tertiles of finish time were adjusted for gender and TTM event (5 or 10 km or 10 miles).
BMI, body mass index; RRI, running-related injury; TTM, Tilburg Ten Miles.

Table 3. Absolute number, mean prevalence, and severity measures of the running-related injuries (RRI)

RRI	Overall	Substantial	Overuse	Acute	Time loss	Medical attention
Absolute number	*n* = 41	*n* = 22	*n* = 35	*n* = 6	*n* = 30	*n* = 14
Prevalence, mean (95% CI)	30.8% (25.6–36.0%)	16.2% (9.9–22.5%)	28.0% (22.7–33.3%)	2.8% (0.6–5.1%)	20.3% (15.1–25.5%)	7.9% (4.6–11.3%)
Severity measures, median (IQR)						
Average severity score	39.5 (22.0–68.0)	67.5 (53.4–80.0)	39.5 (21.0–68.0)	45.8 (28.0–70.5)	55.4 (31.0–78.1)	70.3 (56.8–87.5)
Cumulative severity score	79.0 (28.0–175.0)	155.5 (80.0–284.0	79.0 (28.0–183.0)	54.0 (28.0–127.0)	84.0 (37.0–267.0)	274.5 (175.0–380.0)
Average time loss, days	2.4 (0.0–7.0)	6.3 (4.0–9.0)	2.4 (0.0–7.0)	2.5 (1.0–4.0)	4.3 (2.0–7.5)	6.6 (4.0–9.8)
Cumulative time loss, days	3.0 (0.0–14.0)	13.0 (8.0–30.0)	5.0 (0.0–14.0)	2.5 (1.0–8.0)	8.5 (2.0–28.0)	28.0 (9.0–36.0)
Average duration, weeks	4.0 (2.0–4.0)	4.0 (4.0–10.0)	4.0 (2.0–6.0)	2.0 (2.0–4.0)	4.0 (2.0–8.0)	9.0 (4.0–0.0)

95% CI, 95% confidence interval; IQR, 25–75% interquartile range.

reported by five participants. The mean prevalence was higher for overuse than for acute RRIs. The cumulative severity score and cumulative time loss also presented larger values for overuse than for acute RRIs. The average severity score was higher for acute than for overuse RRIs (Table 3). The most commonly reported RRIs were Achilles tendon injury and knee pain, both with 14.6% (*n* = 6). Lumbar pain, plantar fasciitis, and shin splint were also frequent, with 7.3% (*n* = 3).

Economic burden of RRIs

In total, 47 healthcare consultations (four general practitioner consultations, five medical specialist

Table 4. Economic burden of the running-related injuries (RRI)

	Overall	Direct costs				Indirect costs
		Total	General practitioner	Medical specialist	Physiotherapy	Absenteeism from paid work
Costs per RRI, €						
Total, $n = 32$	173.72 (57.17–318.76)	57.97 (26.17–94.00)	3.97 (0.88–8.41)	11.25 (0.00–22.50)	42.75 (18.00–72.00)	115.75 (10.37–253.73)
Overuse, $n = 27$	196.59 (52.32–367.60)	59.41 (25.54–97.10)	2.07 (0.93–5.39)	13.33 (4.97–36.00)	44.00 (15.43–80.57)	137.18 (25.60–292.42)
Acute, $n = 5$	50.20 (11.83–122.20)	50.20 (11.83–120.14)	14.20 (7.89–47.33)	–	36.00 (20.00–120.00)	–
Difference	146.39 (−4.60–323.28)	9.21 (−83.24–84.15)	−12.13 (−45.40–4.31)	–	8.00 (−100.27–75.11)	–
Costs per participant, €						
Total, $n = 53$	104.89 (30.51–198.27)	35.00 (14.10–58.11)	2.40 (0.53–5.08)	6.79 (0.00–18.33)	25.81 (10.87–44.83)	69.89 (3.13–143.44)
Males, $n = 22$	224.27 (44.66–441.52)	63.46 (20.48–115.17)	1.27 (1.00–4.57)	16.36 (5.76–43.83)	45.82 (12.58–91.17)	160.82 (41.25–373.32)
Females, $n = 31$	20.16 (4.78–40.15)	14.81 (4.12–29.24)	3.19 (0.82–8.90)	–	11.61 (2.57–24.04)	5.35 (4.48–19.13)
Difference	204.11 (29.57–404.36)*	48.65 (2.92–106.96)*	−1.92 (−8.04–3.03)	–	34.21 (−0.90–76.25)	155.47 (−4.61–361.92)

All costs are presented in euros (€). Mean values are followed by the respective bias-corrected and accelerated 95% confidence intervals estimated by bootstrapping (2000 replications).
*Significant difference between females and males.

consultations, and 38 physiotherapist consultations) and 13 missing days from paid work were registered. A total cost of €5558.90 was calculated for the 32 RRIs reported by 25 participants during the 18 weeks of follow-up (excluding RRIs reported at baseline). Of these costs, 66.6% (i.e., €3703.90) corresponded to indirect costs (i.e., absenteeism from paid work) and 33.4% (i.e., €1855.00) corresponded to direct costs (i.e., healthcare consultations). The overview of the costs related to RRIs is presented in Table 4. The mean costs per RRI was €173.72 (95% CI €57.17–318.76), and the mean costs per participant was €104.89 (95% CI €30.51–198.27). Overall and direct costs were significantly higher for males than for females.

Discussion

Prevalence, severity, and nature of RRIs

The results of this study present the extent to which RRIs impact health, healthcare utilization, and productivity loss in runners participating in an organized training program preparing them for a specific running event. The participants of the current study can be considered inexperienced runners as most had no experience at all, or had been involved in running practice for less than 1 year. Interestingly, in the current study the point prevalence at baseline and the mean prevalence of RRIs measured prospectively over time presented similar results. This indicates that, at any point in time, the expected proportion of inexperienced runners with RRIs is consistently around 26–36%.

Half of the RRIs caused a moderate or severe reduction in running volume or running performance, or had caused a complete inability to participate in running. In regard to the injury mechanism, most of the RRIs were overuse injuries (85.4%), which is consistent with the literature (Lopes et al., 2012). Although acute RRIs presented a higher average severity score, the overuse injuries presented a higher cumulative severity score, higher cumulative time loss, and higher direct and indirect costs. Therefore, acute RRIs may be considered more severe and expensive at a given time point (i.e., close to onset). However, overuse injuries were more severe and expensive over time, leading to a larger health and economic burden. These results indicate that RRIs have a considerable impact on organized training programs preparing runners for an event, and highlight the need of interventions to prevent RRIs in such population.

The prevalence of RRIs, which was repeatedly measured over time, found in the current study is not comparable with the available literature. Prospective studies have focused on the incidence of RRIs (Videbaek et al., 2015). However, most of these injuries have an overuse mechanism (Lopes et al., 2012). Overuse injuries cannot be linked to a clearly identifiable event. Therefore, it is not possible with certainty to identify the onset of such injuries (Bahr, 2009; Clarsen et al., 2013). Because of this, it has been suggested that the prevalence measured repeatedly over time should be used to report the risk of overuse injuries instead of incidence (Bahr, 2009; Clarsen et al., 2013).

Previous studies have either reported the prevalence of RRIs retrospectively (Hespanhol Junior et al., 2012; van Poppel et al., 2014) or during running events (Hutson, 1984; Fallon, 1996; Lopes et al., 2011; Scheer & Murray, 2011). The 12-month prevalence of RRIs collected retrospectively was about 55% in recreational and marathon runners (Hespanhol Junior et al., 2012; van Poppel et al., 2014). This estimate is higher than the prevalence of previous RRIs found in the current study (28.3%). Differences in methodology and populations hamper the comparison of the prevalence of RRIs among studies, and partly explain the variation observed among the prevalence estimates. However, it is noteworthy that the current study was the first to report the prevalence of RRIs repeatedly over time (i.e., longitudinally), which reduces the risk of recall bias (Junge & Dvorak, 2000).

Economic burden of RRIs

This study presents, to the best of our knowledge, the first report of direct and indirect costs related to RRIs in runners participating in an organized training program. The mean cost of RRIs found in the current study, which was €173.72 (95% CI €57.17–318.76), was comparable with the mean cost of physical activity-related injuries in children aged 10–12 years during one school year in the Netherlands, which was €188 (SD €317) (Collard et al., 2011). During a volleyball season, one ankle sprain was estimated to cost on average €360.60 (SD €426.73) (Verhagen et al., 2005), which is higher than the cost per RRI found in the current study. However, the cost of ankle sprains per participant was €18.94 (€147.09) (Verhagen et al., 2005), which was considerably lower than the costs of RRIs per participant.

The health benefits of running for the individual and the running-related economic savings for society (related to reducing the risk of chronic diseases) outweigh the health and economic consequences of RRIs (Hatziandreu et al., 1988; Chakravarty et al., 2008). Nonetheless, as we have shown in the current study, the overall (i.e., the direct plus the indirect) cost of RRIs per participant during an organized running program is about €105. Given the high popularity of running events, and consequently the substantial number of runners participating in organized training programs preparing them for these events, the absolute societal costs of RRIs on the short term can be considered a matter of concern for public health; costs that can be prevented by implementing preventive advices and programs.

The overall costs of RRIs were higher for males than for females. These results can be explained by the mean prevalence of RRIs, which was higher for males than for females. Previous studies also suggested that the incidence of RRIs in males is higher (Buist et al., 2010; Hespanhol Junior et al., 2013); therefore, RRIs may have a larger impact in men. These results indicate that the prevention of RRIs should have a particular attention in males, who may have a distinct behavior toward running participation or RRI prevention compared with females. Therefore, future studies should investigate differences in running behavior between men and women to confirm this hypothesis, and also to clarify how specific preventive interventions tailored to these groups could be implemented.

The indirect cost of RRIs was twofold higher than the direct cost in the current study. This is in line with previous studies that reported the costs of sports injuries in other populations (Verhagen et al., 2005; Cumps et al., 2008; Hupperets et al., 2010; Janssen et al., 2014). The number of healthcare consultations was higher than the number of missing days from paid work. However, the missing days from paid work had a higher cost to society than the direct access to health care. This indicates that healthcare utilization (direct cost) is not the main contributor to the economic burden of sports-related injuries. Instead, productivity loss is the cost driver with a significant impact on societal financial resources. This shows that productivity loss is, from a public health standpoint, a meaningful outcome and severity measure in both observational as well as intervention studies (van Mechelen et al., 1992; van Dongen et al., 2014).

Strengths and limitations

The strengths of this study include the prospective measurement of the prevalence of RRIs and costs data, which are scarce in the literature. To the best of our knowledge, this was the first study to provide evidence about the prevalence of RRIs measured repeatedly over time, and the costs of RRIs. This study reported RRIs irrespective of time loss or medical attention, a characteristic commonly found in the definition of RRI in most studies (van Gent et al., 2007; Lopes et al., 2012). Using a definition restricted to time loss or medical attention could underestimate the impact of RRIs on health and costs. In fact, 24.4% ($n = 10$) of the RRIs had caused no time loss and did not require medical attention. Also, different severity measures were evaluated (severity score, time loss, medical attention, and costs) in order to establish the burden of RRIs in runners participating in organized training programs.

This study had also some limitations. The participants of this study were recruited from the TTM clinics, which may limit the generalizability of our results to other organized training programs. The RRIs were self-reported and then classified by a healthcare professional (LCHJ) using the description given by the participants. A confirmation of the RRI diagnoses during face-to-face medical consultations was not possible due to logistic reasons. The current study used standard Dutch government sources to assign unit cost values to cost categories (Centraal Bureau voor de Statistiek, 2014; van Roijen et al., 2010). This methodology is widely accepted and recommended for cost analysis (Lambeek et al., 2011; van Dongen et al., 2014). However, it is important to realize that the cost results were estimated and do not represent actual costs.

Perspectives

The results of this study are important to inform professionals involved in running clinics about the risk and the societal burden of RRIs in runners participating in organized running programs preparing them for an event. Such results are scarce in the literature, especially the direct and indirect costs. This study showed that, with the method used, it is possible to identify minor RRIs (i.e., non-substantial, non-time loss, and non-medical attention RRIs). The implication is that, in practice, the ability to intervene in these minor injuries preventing them to become more severe in the future can be optimized. This could be carried out by monitoring the injury status of the runners with the OSTRC questionnaire and by providing feedback to the runners, trainers, or stakeholders, or yet referring the runners to a healthcare professional (Clarsen et al., 2014; Verhagen & Bolling, 2015). Also, the results of this study suggest that future injury prevention programs for participants of running clinics should focus on overuse RRIs, especially Achilles tendon injury and knee pain. Preventing such injuries will lower medical costs, but will lower even more costs related to productivity losses.

Key words: Sports injury, epidemiology, epidemiological monitoring, public health surveillance, costs and cost analysis.

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