Chapter 6

The impact of injury definition on injury surveillance in novice runners

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ABSTRACT

Objectives: Despite several consensus statements, different injury definitions are used in the literature. This study aimed to identify the impact of different injury definitions on the nature and incidence of complaints captured during a short-term running program for novice runners.

Design: Prospective cohort study.

Methods: 1,696 participants completed weekly diaries on running exposure and musculoskeletal complaints during a 6-week running program. These data were used to compare six different injury definitions (presence of running-related pain, training-reduction, time-loss of one day or one week). Injuries were registered under these different definitions. Consequently incidence and the nature of complaints were compared between definitions.

Results: The different injury definitions resulted in incidences that varied between 7.5% and 58.0%, or 18.7 and 239.6 injuries per 1,000 hours of running. The median duration of injury complaints was 4 to 7 days for injuries registered under a ‘day definition’, while complaints registered under a ‘week definition’ lasted 20 to 22 days. For running-related pain injuries the median of the maximum amount of pain was scored 3.0. In training-reduction and time-loss injuries these median values were scored between 5.0 and 7.0. No significant differences in anatomical locations between injuries that were registered under a ‘day definition’ or a ‘week definition’ were found. Injuries registered under a time-loss definition were located relatively more often at the knee, while complaints at the pelvis/sacrum/buttock were captured more often under a running-related pain definition.

Conclusions: Injury definitions largely impact injury incidence. Location of injury is also affected by choice of injury definition. This stressed the need for standardised injury registration methods.
INTRODUCTION

Much research has been done on running-related injuries. Many incidence reports are thus available, with incidence proportions varying greatly from 1.4% to 94.4% [1]. Study design, follow-up time, running population, method of injury registration (injury assessment) and employed injury definition are all argued to form the basis for the large variety in reported incidence proportions [2]. And yet, in studies in which most of these factors were identical (i.e. study design, running population and injury assessment), incidence proportions still varied between 10.9% and 84.9% [3, 4].

Differences in injury definition logically impact these differences in reported injury incidences. Injury definitions can be generally categorised into ‘all complaints’, ‘medical attention incidents’ and ‘time-loss injuries’ [5]. Incidences will be highest when all complaints experienced during sports are registered, regardless of the consequences and origin of these complaints [6]. Including ‘all complaints’ as injury definition, however, is used less frequently in the literature and appears predominantly in research conducted during running events [7, 8]. It is, however, the definition of an injury as proposed by the recent consensus statement for epidemiological studies in athletics [9]. A medical attention definition is also used often to assess injury occurrence during events [7, 10, 11]. A disadvantage of the latter registration method is that differences in accessibility to medical support largely influence the accuracy of the collected data [12].

In research among runners, time-loss definitions are the most-often applied [13]. The large variety in application of time-loss definitions, however, might directly result in the range of incidence proportions found in literature [14]. Firstly, the duration of time loss to be considered an injury varies between studies. In some studies one training day missed due to running-related pain was considered a time-loss injury [2, 15], in others three consecutive training sessions or a complete week had to be interrupted in order to define an event as an injury [3, 16, 17]. Secondly, differences in the degree of time loss exist. Time loss can, for instance, be interpreted as being unable to do running practice [18, 19] or only as a reduction in training (lower intensity, shorter distance or duration) as a result of running-related pain [20-22].

To date, the influence of different injury definitions on injury incidence and nature of injury complaints among runners is unknown. Hence the primary aim of this study is to identify the impact of different injury definitions on the reported incidence in novice runners by applying different definitions in one large data set. The secondary aim is to compare characteristics of injuries that were registered under different injury definitions.
METHODS

Data from the NLstart2run study were used for the stated study purpose. The NLstart2run study is a multi-centre prospective cohort study among novice runners participating in a “Start to Run” program that prepared participants in 6 weeks (with 2-3 training sessions per week) for a 20-minute run [23]. The study design, procedures and informed consent process were approved by the Medical Ethics Committee (no. 2012/350) of the University Medical Center Groningen (UMCG), the Netherlands. The study is registered in the Netherlands Trial Registry (NTR3676).

Registrants of the 2013 ‘Start to Run’ program (N=7,660), organized by the Dutch Athletics Federation, were asked to participate in the study. Participants aged between 18 and 65 who agreed to participate and completed a baseline questionnaire with personal characteristics were included in the study (N=1,772). Participants who reported data on running exposure via an online running log during the 6-week running program were included in the analysis (N=1,696).

A weekly digital running log had to be completed during the running program. This log asked for the number of planned training sessions as well as information on running activity (yes/no), running exposure (minutes of running) and pain experienced during running. Participants were asked not to report muscle soreness or blisters during the pain registration.

When pain was the reason for not starting a training session or was present during or immediately after the session, additional information was requested. Participants were asked to score the maximum amount of pain perceived during the day on an 11-point numerical rating scale (NRS) ranging from 0 (no pain) to 10 (worst pain imaginable). A body chart was used to obtain the locations of the complaints. Participants were also asked whether or not the pain was caused by running (running-related pain). Participants also reported the outcome of that training session (i.e. was it possible to finish the planned training session despite the pain). This information was used to register the injuries according to the different injury definitions.

Injury definitions were categorised into running-related pain (regardless of the consequences for training), training-reduction (reduction in intensity, speed, distance or duration) and time-loss (i.e. complete absence from training). These definitions were also separated into ‘day’ and ‘week’ based on the minimal duration of complaints. This categorisation resulted in six different injury definitions/operationalisations: one-day running-related pain injuries (RRP-day), one-day training-reduction injuries (TR-day), one-day time-loss injuries (TL-day), one-week running-related pain injuries (RRP-week), one-week training-reduction injuries (TR-week) and one-week time-loss injuries (TL-week) (Table 1). Injury incidences during the running program were calculated based on these six injury definitions from the training data that were collected using the digital running log.
The impact of injury definition on injury surveillance in novice runners

Table 1: Different injury definitions that were compared in the present study.

<table>
<thead>
<tr>
<th>Day definitions</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Running-related pain injury, one day</td>
<td>Running-related pain experienced during ≥ 1 (planned) running session, regardless of the consequences for that running session.</td>
</tr>
<tr>
<td>(RRP-day)</td>
<td></td>
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<tr>
<td>Training reduction injury, one day</td>
<td>Running-related pain experienced during ≥ 1 (planned) running session, influencing that session (reduction in speed, distance or intensity).</td>
</tr>
<tr>
<td>(TR-day)</td>
<td></td>
</tr>
<tr>
<td>Time-loss injury, one day</td>
<td>Presence of running-related pain, resulting in the absence from ≥ 1 planned running session.</td>
</tr>
<tr>
<td>(TL-day)</td>
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</table>

<table>
<thead>
<tr>
<th>Week definitions</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running-related pain injury, one week</td>
<td>Running-related pain experienced during all (planned) running sessions for one week or more, regardless of the consequences for the running sessions.</td>
</tr>
<tr>
<td>(RRP-week)</td>
<td></td>
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<tr>
<td>Training reduction injury, one week</td>
<td>Running-related pain experienced during all (planned) running sessions for one week or more, influencing all running sessions for one week (reduction in speed, distance or intensity).</td>
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<tr>
<td>(TR-week)</td>
<td></td>
</tr>
<tr>
<td>Time-loss injury, one week</td>
<td>Presence of running-related pain, resulting in absence from all planned running sessions for one week or more.</td>
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<td>(TL-week)</td>
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</table>

Only the first registered injury was taken into account in the analyses. A comparison was made between the characteristics of all injured participants that were identified under the different injury definitions. Given the population of novice runners, it was assumed that participants had not previously suffered from running-related injury complaints. Incidence proportions (as percentage) and densities (number of injuries per 1,000 hours of running exposure) with corresponding 95% confidence intervals (CI) were therefore calculated for injuries that were registered under each of the six definitions. Hours of running exposure were measured from the start of the program until an RRI occurred or until the end of the running program. For each injury, the week of occurrence was determined as well as the maximum amount of pain perceived during the injury period. Duration of injury complaints was calculated as the number of days until the participant completed a training session without injury complaints or until the end of the running program. These data were reported as medians with inter-quartile ranges (IQR). The affected body parts were determined for each injury and were categorised into complaints affecting the Achilles tendon, foot, ankle, calf, shin, knee, dorsal thigh (hamstrings), ventral thigh (quadriceps), groin, hip or pelvis/sacrum/buttock. Multiple body locations could be affected in a single injury.
Injury characteristics of complaints that were ‘missed’ under one definition (stricter definition) but registered under another (broader definition) (e.g. TR-day vs. TL-day injuries) were compared. These comparisons were made for TR-day and TL-day, TR-week and TL-week and TL-day and TL-week injuries. These definitions were chosen because they were used frequently in the literature, and the comparisons give insight into the consequences of choosing one definition over another [13, 24, 25].

Chi-square ($\chi^2$) tests were used to compare incidence proportions as registered under the different injury definitions. When a significant difference was detected, pair-wise comparisons with the Holm adjustment for multiple comparisons were conducted to identify which proportions were significantly different. An ANOVA with Bonferroni correction was conducted to compare participant characteristics of the injured runners that were registered under the different injury definitions. R (version 3.1.1; R Core Team 2014) was used for all analyses.

**RESULTS**

In total 1,696 novice runners were included in the analyses. The majority was female (78.5%). Participants were aged 43.3 ± 10.0 years and had a body mass index (BMI) of 25.5 ± 4.0 kg/m$^2$. Most participants had no previous running experience (60.3%) and had not been involved in other sports activities in the previous year (56.2%).

Incidence proportions and densities with corresponding 95% confidence intervals as registered under the different injury definitions are shown in Table 2. Incidence proportions varied significantly ($\chi^2(5)=1475.9$, $p<0.001$), ranging from 7.5% (TL-week) to 58.0% (RRP-day). Incidence densities ranged from 18.7 (TL-week) to 239.6 (RRP-day) injuries per 1,000 hours of running. The results of the post-hoc pair-wise analyses showed that the incidence proportion of RRP-day injuries was higher compared to the injuries registered under the other definitions. The incidence proportion of TR-day injuries (28.8%) was significantly higher than that of TL-day injuries (22.5%). A comparison between ‘day definitions’ and ‘week definitions’ showed that the incidence proportions of all ‘day injuries’ was higher than that of the corresponding ‘week injuries’. Within the ‘week definitions’, the number of RRP-week injuries was higher than the number of TR-week and TL-week injuries. No significant differences in incidence proportion between TR-week (9.6%) and TL-week (7.5%) were found.

Comparisons of characteristics of the registered injured runners under the different injury definitions, showed no significant differences for age ($F=(5,2584)=1.98$, $p=0.078$), BMI ($F=(5,2578)=0.53$, $p=0.754$) or gender distribution ($\chi^2(5)=2.1$, $p=0.834$). Characteristics of the injuries registered under the different definitions are shown in Table 2. Most injuries occurred in weeks 2 and 3 of the running program. RRP-day and RRP-week injuries occurred significantly earlier compared to TR-day, TR-week, TL-day and TL-week injuries ($\chi^2(5)=214.2$, $p = <0.001$). Median duration of the injuries registered under a one-day definition ranged
from 4.0 (TR-day and TL-day) to 7.0 (RRP-day) days. Median duration of the equivalent ‘week injuries’ ranged from 20.0 (TL-week) to 22.0 (RRP-week) days. Median duration of the ‘week injuries’ was significantly longer, and RRP-day injuries persisted significantly longer than TR-day and TL-day injuries ($\chi^2(5)=634.1, p=<0.001$).

The maximum amount of pain experienced during the injury period ranged from a median NRS of 3.0 to 6.0 for the ‘day injuries’ and from 3.0 to 7.0 for the ‘week injuries’. The maximum amount of pain for RRP-day and RRP-week injuries scored significantly lower than the corresponding training-reduction and time-loss injuries ($\chi^2(5)=307.1, p<0.001$) (Table 2).

The anatomical distribution for the different injury definitions is shown in Figure 1. For all definitions, the highest relative number of injuries was located around the knee. The injury proportion in the ventral and dorsal thigh (i.e. upper leg) was lowest for all definitions. A significant difference in distribution of knee injuries between the definitions was found ($\chi^2(5)=15.4, p=0.009$). Knee injuries were relatively more prevalent in TL-day injuries than in RRP-day injuries. In addition, TR-day injuries were relatively more often located at the calf compared to RRP-day injuries ($\chi^2(5)=16.0, p=0.007$). The proportion of injuries to the pelvis/sacrum/buttock region was higher in RRP-day injuries compared to TR-day, TL-day, TR-week and TL-week injuries ($\chi^2(5)=37.3, p<0.001$).

A comparison between the TR-day (N=489) and TL-day definition (N=382) showed that 107 runners were injured when using a TR-day definition, but the injuries were ‘missed’ under a TL-day definition. Characteristics of these ‘missed’ injuries were compared to the TR-day injuries. Median duration of the ‘missed’ complaints was significantly shorter compared to the TR-day injuries ($U=31918, p<0.001$). The anatomical distribution of the missed complaints compared to the TR-day injuries was significantly different for knee complaints and complaints located at the pelvis/sacrum/buttock. In the ‘missed’ injuries, the knee was affected less often (16.7%) compared to the TR-day injuries (26.9%) ($\chi^2(1)=7.0, p=0.008$). The opposite was true for injuries located at the pelvis/sacrum/buttock (12.5% in ‘missed’ injuries vs. 4.9% in TR-day injuries) ($\chi^2(1)=11.3, p<0.001$). Similar comparisons were made for TR-week with TL-week and TL-day with TL-week injuries. Median duration of the ‘missed’ complaints was significantly shorter for all comparisons (TR-day vs. TL-day, TR-week vs. TL-week and TL-day vs. TL-week). No other differences were found.
Table 2: Characteristics of the injuries registered under each injury definition.

<table>
<thead>
<tr>
<th>Injuries (N)</th>
<th>Incidence proportion (95% CI)</th>
<th>Incidence density (95% CI)</th>
<th>Duration of complaints (days)*</th>
<th>Maximum pain score*</th>
<th>Week of occurrence*</th>
</tr>
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<tbody>
<tr>
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<tr>
<td>Day definitions</td>
<td></td>
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<tr>
<td>1. RRP-day</td>
<td>983</td>
<td>58.0% (55.6%-60.3%)&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>239.6 (224.6-254.6)</td>
<td>7.0 (14.0)&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>3.0 (3.0)&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
<tr>
<td>2. TR-day</td>
<td>489</td>
<td>28.8% (26.7%-31.1%)&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>79.3 (72.2-86.3)</td>
<td>4.0 (11.0)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.0 (5.0)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>3. TL-day</td>
<td>382</td>
<td>22.5% (20.6%-24.6%)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>59.4 (53.5-65.4)</td>
<td>4.0 (11.8)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.0 (6.0)</td>
</tr>
</tbody>
</table>

| Week definitions                                     |                                |                             |                               |                      |                     |
| 1. RRP-week  | 446                            | 26.3% (24.2%-28.5%)<sup>a,b</sup> | 77.2 (70.0-84.3)              | 22.0 (18.0)           | 3.0 (3.0)<sup>a,b</sup> | 2.0 (2.0)<sup>a,b</sup> |
| 2. TR-week  | 163                            | 9.6% (8.3%-11.1%)              | 24.2 (20.4-27.9)              | 21.0 (18.0)           | 7.0 (3.0)           | 3.0 (2.0)           |
| 3. TL-week  | 127                            | 7.5% (6.3%-8.9%)               | 18.7 (15.4-21.9)              | 20.0 (15.5)           | 7.0 (4.5)           | 3.0 (2.0)           |

* Results reported as: median (inter-quartile range).
  a: Significantly different from definition 2.
  b: Significantly different from definition 3.
  c: Significantly different from corresponding week definition.
Figure 1: Anatomical distribution of injuries as registered under the different injury definitions (a significantly different from RRP-day definition).
DISCUSSION

This study aimed to identify the effect of different injury definitions on the reported incidence and nature of injuries in novice runners participating in a 6-week running program. To this end, six different injury definitions were applied to the same dataset. The results of this study show that, depending on definition, incidence proportions varied between 7.5% and 58.0% and incidence densities ranged from 18.7 to 239.6 injuries per 1,000 hours of running. In the current study the different definitions were applied to the same dataset, hence the differences in incidence were purely the result of the definitions used, instead of study design, follow-up period or population of runners followed. It should therefore not be surprising that injury proportions for runners reported in the literature vary greatly, with values between 1.4% and 94.4% [1].

In the present study definitions were separated into day and week definitions. Using day and week definitions, severity of the injuries (in terms of consequences for training) increases from running-related pain injuries via training-reduction injuries to time-loss injuries. From this perspective, it seems contradictory that the least severe injuries persisted the longest (RRP-day and RRP-week). This however can be explained by the fact that the definitions for these injuries were less strict, which automatically leads to the inclusion of mild symptoms that follow more serious ones. For instance, a runner that sustained a TL-day injury might have picked up running after four days of training absence. It might nonetheless be possible that RRP problems were still present after restarting with running. The complaints considered by the TL-day definition (i.e. complete absence from training), however, were over, so duration of the TL-day injury remained four days.

Independently of injury definition, the highest relative number of injuries was located at the knee. This is in line with previous research among novice runners [2, 26]. Still, relatively fewer RRP-day injuries were located at the knee compared to TL-day injuries. This suggests that knee complaints more often lead to time loss. Likewise, one-day calf complaints are more likely to affect training (i.e. TR-day injuries). On the other hand, pain in the pelvis/sacrum/buttock region is mostly present in RRP-day injuries, therefore complaints in this region are less likely to affect running capability. These findings were supported by the comparison of participants that sustained a TR-day injury but no TL-day injury. These ‘missed’ injuries were located less often at the knee, which also indicates that knee complaints resulted more often in time loss. Injuries located at the pelvis/sacrum/buttock region were overrepresented in the ‘missed’ injuries, indicating that these injuries did not often result in time loss. Distribution of the injury sites is thus affected by injury definition. Future research on specific injury complaints might therefore choose a specific injury definition based on the injuries of interest (e.g. TL definition for knee complaints or RRP definition for lower back complaints). It should be noted, however, that these differences are small.
In the current study a distinction was made between training-reduction injuries and time-loss injuries. No significant differences in incidences, participant characteristics or injury characteristics were found between TR-week and TL-week injuries. It is therefore justified to refer to training-reduction injuries as time-loss injuries, as recommended in the recent consensus statements for epidemiological studies in athletics and recreational running [9, 27]. Application of a time-loss definition presents some difficulties, especially for sporting activities in which most of the injuries are attributed to overuse (e.g. running) [28]. Overuse injuries are often characterised by a slow, gradual appearance of problems with pain during sports activities that have a recurrent character. Such pain does not necessarily result in functional limitations (i.e. training-reduction or time-loss) [28], so many of these overuse problems will not be captured under a time-loss definition.

The present study shows that injury definition has a major impact on injury incidence and also affects anatomical locations of injury complaints. It is therefore advisable to standardise injury registration methods. The current study aimed at examining the impact of different injury definitions, instead of selecting the best injury definition. In fact, each injury definition serves a different purpose, which makes it difficult to use one standardised definition [14].

A different tactic was chosen in the Oslo Trauma Research Center (OSTRC) overuse injury questionnaire [28]. This questionnaire was developed to monitor overuse problems over time, irrespective of its consequences for training. Severity of the problems is expressed in a score. This is a promising tool, because both small complaints and severe injuries can be captured over time with a single questionnaire. The questionnaire does have some limitations though. For instance, the scores that correspond to the different answer options are more or less arbitrary, stimulate recall bias and hinder a continuous outcome. Since the tool was developed to monitor overuse problems, it is not possible to identify conventional injuries (e.g. time-loss injuries) from this questionnaire’s results. An adapted version of the questionnaire was developed in which illnesses and acute injuries can also be registered, however the above mentioned limitations remained [29]. Ideally, a questionnaire should be developed that addresses these issues and can be used to monitor both overuse complaints and register time loss injuries. Ideally, severity of the physical complaints is expressed in a continuous score and different severity scores can be related to conventional injury definitions. This would create a standardised tool for monitoring overuse problems as well as registration of injuries.

A few limitations of this study should be noted. In the current study, injuries were registered based on completed running log data. No information on medical attention injuries was reported in the training log, therefore no information on injury incidence obtained with this injury definition was available. Further, only the first injury was taken into account in the
analyses. This might have led to an underestimation of injury incidence, but this effect is probably small due to the relatively short duration of the running program. Finally, only runners participating in a ‘Start to Run’ program were followed in this study so it is not possible to generalise these results to more experienced runners.

**Conclusion**

The results of this study showed that injury definition largely impacts injury incidence. As expected, injury incidence was higher in ‘day’ than ‘week’ definitions, while duration of complaints was higher in the latter. The nature of the injury complaints did not differ between ‘day’ and ‘week’ definitions. Knee complaints often led to time loss, while complaints in the pelvis/sacrum/buttock region seldom affected training routine. These differences indicate that in addition to incidence, site of injury is also affected by choice of injury definition. This stresses the need for standardised injury registration methods.

**Practical implications**

- Injury definitions influence injury incidence to a large extent, however, the nature of injury complaints was not different for ‘day’ and ‘week’ definitions.
- Distribution of the anatomical location of injury complaints is affected by injury definition.
- This paper may facilitate a change in the methods used for injury registration and surveillance of overuse injuries which would lead to more reliable and comparable evidence.
- The injury definition is of high importance for clinical interpretation of study results.

**ACKNOWLEDGEMENTS**

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Chapter 6


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