Injuries can have a major impact on the physical performance and academic career of physical education teacher education (PETE) students. To investigate the injury problem, risk factors, and the impact of injuries on academic success, 252 PETE students were followed during their first semester. Risk factor analysis was conducted by means of logistic regression analysis with a differentiation for upper body, lower body, acute, overuse, and severe injuries. An incidence of 1.26 injuries/student/semester was found. Most injuries involved the lower body (61%), were new injuries (76%), occurred acutely (66%), and were sustained during curricular gymnastics (25%) or extracurricular soccer (28%). Significant risk factors for lower body acute injuries were age (OR=2.14; \(P=.01\)), previous injury (OR=2.23; \(P=.01\)), and an injury at the start of the year (OR=2.56; \(P=.02\)). For lower body overuse injuries, gender (OR=2.85; \(P=.02\)) and the interval shuttle run test score (OR=2.44; \(P=.04\)) were significant risk factors. Previous injury (OR=2.59; \(P=.04\)) and injury at the start of the year (upper body: OR=4.57; \(P=.02\); lower body: OR=3.75; \(P<.01\)) were risk factors for severe injuries. Injury-related time loss was positively related to total academic success (\(r=.20; P=.02\)) and success in theoretical courses (\(r=.24; P<.01\)). No association was found between time loss and academic success for sport courses.

**KEYWORDS**
injury risk, risk factor analysis, severe injuries

1 | INTRODUCTION

Injuries can be highly disadvantageous. They can lead to reduced physical performance, high medical costs, and in extreme cases can be career-ending. Injuries in PETE students are professionally involved in sports, and therefore, injuries in PETE students need special attention. Several studies have described the injury problem in PETE students in the past decades. Injury incidence in PETE students ranges from 0.85 to 2.1 injuries/y. This is relatively high compared to the general active population, which has an injury incidence of 0.36 injuries/y.

The cause of injuries is multifactorial. Several risk factors have been found to apply in sport-active populations, for instance previous injury, female gender, higher age, high exposure to sports, high fat percentage, and a lower endurance capacity. Recent literature shows that risk factors can be differentiated for acute and overuse injuries and for severe injuries. There is little up-to-date literature on risk factors in PETE students, and the available studies do not differentiate between acute and overuse injuries and the severity of injuries. Furthermore, to our knowledge, the impact of these injuries on the academic career of PETE students is unknown.

The main goal of this study was to describe the injury problem in PETE students in terms of incidence, circumstance, mechanism, type, localization, and severity. Secondly, this study aimed to investigate contributions of risk factors including previous injury; gender; age; exposure to sports; fat...
percentage; and endurance capacity for acute, overuse, and severe injuries. A third aim of this study was to investigate the impact of injuries on academic success.

2 | METHODS

2.1 | Subjects

The study sample consisted of first-year bachelor degree PETE students from the Amsterdam University of Applied Sciences. The first-year PETE program consisted, apart from the theoretical courses, of courses in six different sports (gymnastics, field sports, martial arts, dance, athletics, and swimming) with a scheduled exposure of 11.5 h/wk. In total, 292 students were followed during the first semester, September to February, in academic year 2014-2015.

2.2 | Study procedure

A prospective cohort study design was used. Prior to the start of the academic year, all students underwent a compulsory pre-participation examination where height, weight, and fat percentage by four-point skin thickness were measured by a sport physician.

At the start of the academic year, all students were informed about the study and invited to provide written informed consent and complete a baseline questionnaire if they wished to participate. The baseline questionnaire included questions about sport participation before the start of the academic year (sport discipline and exposure time), current injuries, and injuries in the past year. Injuries had to be specified in terms of localization, type, and duration of time loss. In addition, all students performed an interval shuttle run test (ISRT) to assess endurance capacity. All students were instructed to perform the test with maximal effort. Heart rate frequency was measured (Polar Team2, Polar, Sweden) during the test, and directly after the test, the rating of perceived exertion (RPE) was collected. The continuous variables were categorized as following.

2.3 | Risk factors

The continuous variables were categorized as following. Firstly, fat percentage and ISRT score were categorized as below or above average for men and women separately. Secondly, students were divided into the age groups above and below the average age (19.5±2.0). Thirdly, values for sport exposure before the start of the year and extracurricular sport exposure were categorized into two categories using the median as a cutoff point. Finally, the localization of the injuries was categorized as upper (head, neck, hand/fingers, wrist, lower arm, elbow, upper arm, shoulder, clavicle, chest, ribs, belly, upper back, lower back) or lower body (hip, groin, buttocks, upper leg, knee, lower leg, Achilles tendon, ankle, heel, foot, toe). Risk factor analysis was conducted according to injury categories based on localization (upper or lower body) and mechanism (acute or overuse) of the first sustained injury. All injuries sustained after the first injury were excluded from the risk factor analysis.

2.4 | Data analysis and statistics

Compliance was determined by dividing the number of completed injury registration forms by the total number of forms.
that should have been completed (four for each student). Injury incidence was calculated by dividing the total number of injuries recorded across the semester by the number of students. To investigate associations between risk factors and injuries, a univariate Pearson chi-square test was used. Only, the variables associated with injuries with a $P$-value lower than .2 were entered into a stepwise multivariate logistic regression analysis. For assessing the relationship between injury duration and ECTS credits, the Pearson correlation coefficient was determined. $P$ values lower than .05 were considered as significant. All statistical tests were conducted with IBM SPSS statistics 22 (SPSS Inc., Chicago, IL, USA).

3 | RESULTS

3.1 | Subjects and compliance

During the study, 40 students ended their education or did not respond to any of the questionnaires and were excluded from the study. The causes for ending the education were not recorded. The remaining 252 students were included in the study. Subject characteristics can be found in Table 1. In total, 18 students re-entered the first year and were excluded from the analysis of the impact of injury-related time loss on academic success. Furthermore, 16 students were excluded from the analysis of ISRT score as a risk factor because their score was rated as a submaximal score. At the start of the year, the students reported an average extracurricular sport exposure of 410 min/wk (standard deviation: 238 min/wk; median: 360 min/wk), and during the year, they reported an average extracurricular sport exposure of 265 min/wk (standard deviation 175 min/wk; median: 262 min/wk). In total, 815 completed questionnaires were received, giving an overall compliance of 81%. In total, 142 (56%) students completed four questionnaires, 50 (20%) students completed three questionnaires, 31 (12%) students completed two questionnaires, and 29 (12%) students completed only one questionnaire. From 231 (73%) injuries, the date of recovery was obtained. In 87 (27%) cases, no information about the date of recovery was obtained.

3.2 | Injury characteristics

A total of 318 injuries were registered by 252 students. This equates to a total injury incidence of 1.26 injuries/student/semester. During the semester, 164 (65%) students registered one or more injuries, of which 80 (32%) students sustained one injury, 42 (17%) students sustained two injuries, 24 (10%) students sustained three injuries, 11 (4%) students sustained four injuries, five (2%) students sustained five injuries, and two (1%) students sustained six injuries. Most injuries were new injuries (76%) and acute (66%). Most of the acute injuries occurred during intracurricular sport activities (53%). Intracurricular gymnastics (25%) and extracurricular soccer (28%) were the disciplines with the highest injury incidence (Figure 1). Most injuries were located at the lower extremities (61%) and involved the knee (16%), the ankle (14%), and the anterior side of the lower leg (14%). The lower back (9%) and the shoulder (7%) were the most common injury locations in the upper body. The most common injury locations are presented in Figure 2. Most injuries were muscle strains (18%), contusions (12%), ligament strains (11%), tendonitis (7%), or sore muscles (5%). In some cases, students were unable to define an injury type (7%). Time-loss duration was

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Subject characteristics (mean±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
</tr>
<tr>
<td>N</td>
<td>169</td>
</tr>
<tr>
<td>Age</td>
<td>19.9±2.2</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.82±0.07</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.3±8.0</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>13.4±3.5</td>
</tr>
<tr>
<td>ISRT score</td>
<td>96±18</td>
</tr>
</tbody>
</table>

ISRT, interval shuttle run test.

FIGURE 1  Most common activities where acute injuries (N=210) were sustained

FIGURE 2  Most common injury locations
determined for 231 injuries. Most injuries were severe (43%), followed by moderate (26%), mild (18%), and minimal (14%) injuries. Most overuse injuries (N=43) were found in the severe injury category, and this is illustrated in Figure 3.

3.3 | Risk factor analysis

The results from the risk factor analysis are displayed in Table 2. Gender was a significant risk factor for injuries. Women had a higher risk than men of sustaining an overuse injury in the lower body. The higher age category had an increased risk of sustaining a lower body acute injury. An upper body injury in the previous year was a significant risk factor for sustaining a severe injury. A lower body injury in the previous year was a significant risk factor for sustaining a lower body acute injury. An upper body injury at the start of the academic year was a significant risk factor for sustaining a severe injury. A lower body injury at the start of the academic year was a significant risk factor for sustaining a lower body acute injury and a severe injury. The students with a relatively high ISRT score were less likely to sustain an upper body acute injury and more likely to sustain a lower body overuse injury compared to students with a relatively low ISRT score. Fat percentage, sport exposure before the start of the year, and extracurricular sport exposure were not significant risk factors for any of the injury categories.

3.4 | Relationship between injury and academic success

The total time loss due to injury correlated positively with total obtained ECTS credits ($r=.20; P=.02$) and ECTS credits obtained for theoretical courses ($r=.24; P<.01$). Total time loss was not significantly correlated with obtained ECTS credits for sporting courses ($r=-.01; P=.95$).

4 | DISCUSSION

The main findings of this study are firstly that with an incidence of 1.26 injuries/semester, PETE students have a high risk for sustaining a time-loss injury. Injuries were mainly sustained during intracurricular gymnastics and extracurricular soccer. Secondly, the following risk factors apply to PETE students: female gender, higher age, previous injuries, injuries at the start of the year, and ISRT score. Thirdly, injury-related time loss has a weak positive relationship with academic success.

With an incidence of 1.26 injuries/semester (2.52 injuries/y), PETE students have a significantly higher injury incidence than the 0.36 injuries/y of the general Dutch sport-active population. Compared to previous studies in PETE students, we found the highest incidence. Previous studies by Lysens et al., Twellaar et al., Ehrendorfer, Flicinski, Goossens et al., and Mukherjee found an injury incidence of 1.7, 0.97, 1.37, 2.1, 1.5, and 1.0 injuries/y, respectively. The most important reasons for the differences between the studies are the use of different definitions and methodologies. Several studies used a retrospective approach and found a lower incidence of 1.37 and 2.1 injuries/y. Retrospective study designs are associated with recall errors and can lead to a lower count of injuries when compared to prospective studies. All studies used different injury definitions which makes it difficult to compare the results with our study. In some studies, it is unclear which definition is used. Goossens et al. used a definition based on the consequences: “… the student having to stop the activity and/or suffering from pain during sports participation and/or not being able to (fully) participate in the next planned sports class, training session or match.” Mukherjee used six criteria as an injury definition, which are as follows: (1) injury occurred as a result of the PE curriculum sports participation; (2) injury occurred as a result of training/practice related to the PE curriculum; (3) injury occurred as a result of participation in the other forms of organized sport (eg, leisure, interhall games, varsity sports); (4) the injury may or may not affect academic commitment in any form for any length of time; (5) the injury may or may not require medical attention; (6) any dental injury regardless of time loss.” used the following definition: “A physical discomfort sustained during physical activity that hindered the subject practicing sport lessons at the institute.” defined an injury as any injury “that occurred during the sports workout sessions, and causing at least a 3-day absence from sports.” Our definition is any physical complaint, not necessarily acute injuries, sustained during sport activities, that results in a student being unable to fully take part in sporting activities for at least 1 day. Our definition may be interpreted as less delimited than the definitions of Lysens et al., Goossens et al., and Mukherjee, which helps to explain the higher injury incidence found in our study. This is supported by the fact that we found more injuries with a short time-loss duration compared to the study of Goossens et al. However, we also found substantially more injuries with a time-loss duration of more than 4 weeks. This cannot be

![Figure 3](image-url)
TABLE 2  Risk factors for upper and lower body acute injuries, upper and lower body overuse injuries, and severe injuries for PETE students (N=252). P values for univariate chi-square and multivariate logistic regression analysis are displayed.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Acute injury (N=114)</th>
<th>Overuse injury (N=47)</th>
<th>Severe injury (N=68)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper body (N=41)</td>
<td>Lower body (N=73)</td>
<td>Upper body (N=11)</td>
</tr>
<tr>
<td></td>
<td>UV</td>
<td>MVLR</td>
<td>UV</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>OR (95% CI)</td>
<td>P</td>
</tr>
<tr>
<td>Gender (female)</td>
<td>.86</td>
<td>.55</td>
<td>.81</td>
</tr>
<tr>
<td>Fat% (&gt;mean)</td>
<td>.87</td>
<td>.94</td>
<td>.64</td>
</tr>
<tr>
<td>Age (&gt;mean)</td>
<td>.98</td>
<td>.02*</td>
<td>.77</td>
</tr>
<tr>
<td>Sport exposure</td>
<td>Before start (&gt;median)</td>
<td>.95</td>
<td>.16</td>
</tr>
<tr>
<td>Extracurricular (&gt;median)</td>
<td>.57</td>
<td>.74</td>
<td>.74</td>
</tr>
<tr>
<td>Previous injury</td>
<td>Upper body</td>
<td>.15</td>
<td>2.75 (0.95-7.96)</td>
</tr>
<tr>
<td>Lower body</td>
<td>–</td>
<td>&lt;.01**</td>
<td>2.23 (1.21-4.10)</td>
</tr>
<tr>
<td>Injury at start</td>
<td>Upper body</td>
<td>.16</td>
<td>0.51 (0.06-4.45)</td>
</tr>
<tr>
<td>Lower body</td>
<td>–</td>
<td>&lt;.01**</td>
<td>2.56 (1.17-5.61)</td>
</tr>
<tr>
<td>ISRT score (&gt;mean)</td>
<td>.06</td>
<td>0.44 (0.20-0.97)</td>
<td>.04*</td>
</tr>
</tbody>
</table>

UV, univariate analysis; MVLR, multivariate logistic regression analysis; OR, odds ratio; CI, confidence interval.

*Significant at P<.05.
**Significant at P<.01.
explained by differences in definition use alone. This might indicate that the PETE students in our study actually sustain more and more severe injuries. Differences between the study of Twellaar et al.\textsuperscript{11} and our study may be explained by differences in follow-up period. Twellaar et al.\textsuperscript{11} prospectively followed 136 Dutch PETE students during their 4-year education and found an overall incidence of 0.97 injuries/student/yr. Our study only included the first semester of the first year. Previous research shows that the most injuries are sustained during the first semester (54%) of the first academic year.\textsuperscript{10} A longer follow-up period might lead to a lower incidence. Observations from practice support the hypothesis that injury incidence decreases in the following academic years.

The results in the literature are difficult to compare also due to differences between the PETE programs. For instance, intracurricular exposure time varies from 6.8 h/wk in Singapore\textsuperscript{10} to up to 15 h/wk in Austria.\textsuperscript{6} The students in the current study had an exposure time of 11.5 h/wk intracurricular sports. Intracurricular skiing and ice skating are only seen in the PETE curriculum in Austria.\textsuperscript{6} Intracurricular incidence rates range from 1.96 injuries/1000 h in Belgium\textsuperscript{3} to 2.83 injuries/1000 h in Singapore,\textsuperscript{10} indicating potential differences in the physical demands of the curriculum. Furthermore, the average age of the PETE populations varies from 18.4 years in Belgium\textsuperscript{3} to 25.9 years in Singapore,\textsuperscript{10} indicating potential significant differences in population characteristics. To conclude, our higher observed injury incidence can be attributed to the following factors: (a) In our study, all physical complaints leading to time loss were included; (b) we used prospective data acquisition procedures; (c) the follow-up period was only the first semester, generally the semester where most injuries occur; (d) possibly, the exposure time and physical demands of the curriculum in our study were higher than in most studies (unfortunately, we cannot support this hypothesis because we lack detailed data on exposure time and intensity of the sport courses); and (e) differences in population characteristics may play an important role.

Regarding injury localization in PETE students, our results show that 61% of all injuries were located in the lower extremities. This is in agreement with results of Twellaar et al.\textsuperscript{11}, Flicinski\textsuperscript{7}, Goossens et al.\textsuperscript{3}, Mukherjee\textsuperscript{10} and Goossens et al.\textsuperscript{8}. They found a proportion of lower extremity injuries of 66%, 69%, 74%, 52%, and 72%, respectively. Like our study, most studies found that the knee, ankle, and lower leg were most frequently injured.\textsuperscript{3,6,7,10,11} Our study found that 67% of the injuries were non-recurrent. This is lower, but in line with findings of Lysens et al.\textsuperscript{9}, Goossens et al.\textsuperscript{3}, Goossens et al.\textsuperscript{8} and Mukherjee\textsuperscript{10} who report, respectively, 80%, 70%, 72%, and 74% new injuries. The proportion of acute injuries (66%) in our study agrees with earlier findings of 71%, 65%, and 70% found by, respectively, Twellaar et al.\textsuperscript{11}, Goossens et al.\textsuperscript{3} and Goossens et al.\textsuperscript{8}. That the majority (53%) of all injuries were sustained during intracurricular activities also corresponds with the literature.\textsuperscript{3,10,11} In general, the injury characteristics found in our study correspond to a large extent with earlier findings in PETE students.

Previous injury is the main risk factor for injury identified in our study. This corresponds with results of multiple other studies.\textsuperscript{3,14,15,20} Our study adds that this risk factor can be specific. Previous injury was a specific risk factor for acute lower body injuries and severe injuries. An incomplete recovery of previously injured body parts probably increases the likelihood of a recurrent injury. In our study, women had a significantly higher risk of sustaining a lower body overuse injury when compared to men. This result is not in line with a previous study on PETE students.\textsuperscript{3} The study by Goossens et al.\textsuperscript{3} indicated that gender was not a risk factor for knee, ankle, lower leg injuries, and injuries in general. However, no analysis was executed for overuse injuries in particular. In military personnel, it has been shown that women have an increased risk of sustaining an overuse injury\textsuperscript{16} and an injury in the lower extremities.\textsuperscript{26} A review on risk factors shows that conflicting literature can be found on the relationship between gender and lower extremity injury risk.\textsuperscript{15} Our findings support the literature that indicates that women have an increased risk of sustaining lower body overuse injuries.

In our study, a higher age was found to be a risk factor for lower body acute injuries. Conflicting results have been found in the literature regarding age as a risk factor, with most studies finding an increased injury incidence in higher age categories.\textsuperscript{15} Therefore, our finding regarding lower body acute injuries corresponds with the majority of the literature on this topic.

A relatively high ISRT score was found to be associated with a lower risk for upper body acute injuries and a higher risk for lower body overuse injuries. This does not correspond with earlier findings of Verstappen et al. (1998) who found no relationship between aerobic fitness and injury risk in PETE students. However, they did not control the analysis for type and localization of the injuries. Our findings suggest that students with a high aerobic fitness have a reduced risk of sustaining an upper body acute injury, and this corresponds with most studies of the relationship between aerobic fitness and injury risk.\textsuperscript{15} Our findings also suggest that a higher aerobic fitness is associated with an increased risk for sustaining a lower body injury, and this does not correspond with the literature. However, we hypothesize that the students with a relatively high aerobic fitness were also the students with a large extracurricular sport exposure and therefore are more likely to sustain a lower body overuse injury. The rationale that a high level of sport exposure increases risk for sustaining lower body overuse injuries is in line with literature.\textsuperscript{27} To test the hypothesis, we performed an additional analysis and found a significant association between a high ISRT score and a high extracurricular sport exposure (P<.01).
Fat percentage was not a significant risk factor in our study. Conflicting results can be found in the literature for body composition as a risk factor.\(^\text{15}\) An increased risk for overuse injuries has been found for under- and overweight young conscripts.\(^\text{19}\) The study by Taanila et al. demonstrates a U-shaped relationship between body composition and injury risk. This U-shaped relationship might be the reason that in our dichotomous analysis, no relationship was found.

No relationship was found between total injury-related time loss and academic success for sport courses. Total time loss had a weak positive correlation with total academic success and with results of theoretical courses. This might be explained by our observations that injured students used their injured period to prepare for theoretical classes and examinations. Besides, the curriculum in our study provided occasions to catch up with missed sport courses and their examinations at a later time. This appeared to be sufficient for injured students to catch up with the uninjured students, in their work.

This study has some limitations that need to be addressed. The details of the injuries were registered by the students by means of self-evaluation, and there were no professional diagnoses of the injuries. This means that the injury characteristics should be interpreted with caution. Besides, it is important to point out that our study did not focus on acute sport injuries but on physical complaints leading to time loss, regardless of their origin. This partially explains the high numbers of injuries in our study and explains in particular the injuries caused in an activity other than regular sport activities (Table 2) and suggests that our findings apply to injuries in general.

Only data from one semester are included, and no complete view over the full academic year was obtained. Besides, in total, 110 students did not complete all questionnaires, and in 27% of all injuries, no time-loss duration was determined. This may have biased our results. Furthermore, a rule of thumb is that 10 injuries are needed per risk factor included in the analysis. Not all injury categories had a sufficient number of injuries with respect to the number of risk factors. The results from the risk factor analysis should therefore also be interpreted with caution.

5 | CONCLUSION

We conclude that PETE students have a substantial injury problem. Curricular gymnastics and extracurricular soccer are the main causes for acute injuries. Important risk factors are female gender, greater age, injuries in the previous year, injuries at start of the year, and ISRT score. Despite the high incidence of injuries, injuries had no negative effect on academic success with regard to the sport courses.

Offering occasions to catch up with the missed sport lessons or examinations is probably sufficient to compensate for the injury-related time loss. Future studies should aim to realize a longer inclusion period than in our study and gather more data on duration of time loss due to injury, in order to make a more comprehensive analysis of the long-term impact of injuries on academic success in PE students.

6 | PERSPECTIVES

PETE students have a relatively high risk of sustaining an injury. Curricular gymnastics and extracurricular soccer are major causes of injuries. These activities may be prioritized when applying preventive measures. Previous injury seems to be the most robust risk factor in PETE students. Furthermore, greater age, female gender, and ISRT score are relevant risk factors. This knowledge can be used for improving screening methods for upcoming students by selecting students with a high injury risk and offering them additional advice or support. Injury-related time loss in PETE students should not necessarily be regarded as an academic efficiency problem. Of course, much effort is needed in the area of injury prevention for the purpose of ensuring an optimal academic development of the students, but offering alternative training and examination occasions seems sufficient to enable students to catch up with the uninjured students after recovery from an injury.

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