Introduction

High-intensity functional training (HIFT) has become increasingly popular and there are increasing numbers of participants [1]. It is characterized by a high volume and intensity of training while performing various exercises [2]. The structure of the training is based on a pre-set time for executing a number of repetitions or for each exercise being completed in the shortest possible time, with or without short intervals between the exercises [3]. HIFT was initially developed as a training approach to maintain and increase physical fitness [4]. It is engaging and entertaining, and includes high-intensity exercises with multi-articular exercises, thus emerging as a new training modality [5, 6]. Due to these characteristics, HIFT comprises specific and constantly varied exercises, which include gymnastic movements (e.g. pull-ups and lunges), Olympic weightlifting exercises (e.g. squats, clean, and jerk), and aerobic activities (e.g. rowing and running) [7].

Previous studies have demonstrated that participation in HIFT improved muscle strength, muscular endurance, aerobic fitness, and body composition [8–10]. Smith et al. [10] showed that 10-weeks of HIFT including lifts such as the squat, deadlift, clean, snatch, and...
overhead press performed as quickly as possible improved the aerobic fitness and body composition of healthy subjects. Although some evidence highlights the benefits of HIFT, there is also some concern regarding the likelihood of an injury risk due to its practice [11]. For instance, in a published consensus on extreme conditioning programs (HIFT is classified as an extreme program), the training structure was listed as a negative trait because of fatigue and an increased risk of improper execution of the exercises and consequently an increased risk of injury [12].

Indeed, high-intensity exercises are likely to induce fatigue, which can reduce practitioners’ abilities and concentration, and this in turn might increase the risk of injury [13]. The popularization of some HIFT regimens have brought together people with different characteristics in performing them, and among them around 5% of participants have been found to be addicted to exercise [14]. Addiction to exercise has been associated with attitudes that seem to predispose practitioners to the occurrence of injuries during exercise.

Studies on injury prevalence related to HIFT practice reported an incidence ranging from ~2–2.5 injuries per 1000 hours of practice [7, 13, 15]. It was specifically found that injured practitioners had significantly greater training exposure and length of participation/experience in HIFT than uninjured subjects. This high injury rate may be explained by the repetitive performance of highly-complex technical exercises at a high-intensity [7]. Moreover, as skill and strength level improve, practitioners are more likely to perform more technical exercises with heavier loads under fatiguing conditions, and consequently increase the likelihood of injury [16].

Furthermore, previous studies have found an association between participation in HIFT competition and injury rate, but this association was not significant when the model was adjusted for other variables (i.e., practice time) [3, 13]. In these studies, it is noteworthy that the competitive level of practitioners (e.g., amateur, regional, national) was not considered. This is important because the training demand (i.e., relative load and complexity of exercises) required for practitioners competing at the national level may be different from those who compete in the amateur or regional level, and as a consequence the likelihood of injury may differ between them. However, whether participation in different competition level affects the likelihood of injury is still unknown and needs to be addressed.

Since there has been an exponential increase in participation in HIFT, studies are necessary in order to understand the risk of injury as well as to help trainers to identify the anatomical parts with a greater incidence of injuries and their respective causes. Therefore, the aim of this study was to verify the anatomical sites with the highest occurrence of injuries and the number and possible risk factors for injuries in HIFT practitioners in the last six months. The results of this research can be used to determine the relative safety of HIFT protocols and to identify the potential factors which place practitioners at greater risk of injury.

Materials and Methods

Participants

The sampling process was intentional and non-probabilistic. Five Brazilian training centers were invited to participate in the present study. However, only three training centers agreed to participate. Thus, a total of 300 practitioners were invited to participate, however, only 213 practitioners (~71 practitioners in each training center), of both genders, volunteered and completed the survey (Table 1). Participants were categorized by practice time into beginners, intermediate, advanced and elites according to the criteria established by the American College of Sports Medicine [17]. All participants were informed about the risks and benefits of the study prior to signing the informed consent form. The inclusion criteria were: (i) over 18 years old, (ii) complete the questionnaire; (iii) has been practicing HIFT for 3 months or longer; (iv) practices HIFT at a minimum weekly frequency of two times per week. Participants who did not complete the questionnaire were excluded from the study. The study was approved by the local ethics research committee (CAAE: 98795018.0.0000.5537, N. 3.002.329) and followed all of the ethical standards set forth in the Helsinki Declaration, and also meets the ethical standards of the International Journal of Sports Medicine [18].

Procedures

This was a retrospective study on injury incidence and prevalence in HIFT practitioners. The researchers spent three consecutive days in each of the HIFT facilities conducting the survey with the aim of recruiting and explaining the project to the largest number of participants. The participants were clarified about the sections and subsequent questions prior to applying the questionnaire, and the explanations additionally also existed in the questionnaire itself in order to minimize errors in interpreting the questions. There was an explanation of the term “injury” in the section corresponding to the injury history in the modality, and the participants were encouraged to get in touch with the researchers who were always available to the participants whenever they had doubts. Finally, each survey was reviewed by the researchers after delivery for correct use in data analysis.

The information contained in the questionnaire was used to provide descriptive, retrospective epidemiological information on “injuries” associated with HIFT. Although the retrospective design has some limitations for epidemiological research on injuries [19], it seems that such issues are less problematic in athletes in weight training sports who routinely engage in regular training [20, 21].

<table>
<thead>
<tr>
<th>Variables</th>
<th>Classification</th>
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<th>P value</th>
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<tr>
<td></td>
<td>Total (n = 213)</td>
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<tr>
<td></td>
<td>Injured (n = 82)</td>
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<td></td>
<td>Uninjured (n = 131)</td>
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<td>Age (years)</td>
<td>29.74 ± 6.54</td>
<td>1.55</td>
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<td>30.69 ± 7.10</td>
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<td>29.14 ± 6.11</td>
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<tr>
<td>Height (cm)</td>
<td>169.43 ± 8.68</td>
<td>-0.21</td>
<td>0.83</td>
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<td>169.25 ± 8.24</td>
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<td>169.55 ± 8.98</td>
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<td>Body mass (kg)</td>
<td>72.92 ± 12.18</td>
<td>0.33</td>
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<td>73.34 ± 11.36</td>
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<td>72.66 ± 12.71</td>
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Instruments

The questionnaire used in the study was adapted from a model proposed in the literature [13] and there were similar questions to a retrospective survey of injuries in athletes [20]. In addition to the questions already contained in the questionnaire, questions related to the participants’ profile (e.g., age, gender, height, body mass and their practice modality) were added. Content validity was performed through a review by coaches, two professors/researchers and by a sports science professional with expertise in the researched area. Next, the questionnaire was tested at a training center with practitioners to identify the clarity of the questions, and the questions were modified, as necessary, based on the feedback from the participants after test application. Finally, proper corrections were made when any doubts in the questions existed, and the questionnaires were later implemented in the training centers that had agreed to participate in the present study.

The HIFT practitioners individually completed 23 questions divided into four sections and addressing the participants’ profile (age, gender, stature, body mass), participation in the modality (category, practice time, weekly frequency, session duration), their injury history (if there was any injury in the last six months, which part was injured, if the injury was recidivist, if the injury had occurred prior to the modality practice, in what way the injury occurred, what caused the injury according to the participants (inadequate techniques, fatigue, high loads, repetitive effort and others), and the type of treatment used to manage the injury (if the participant had an injury, they were asked to mark the exact location of the injury on an illustrated representative anatomical figure with an “X”). Fig. 1 and their activity in HIFT (if the practice was aimed at fitness, whether they participated in competition and at which level they competed). Participant responses were directed to be based on their last six months of practice or the entire practice period for participants with <6 months of practice. It is worth mentioning that the lesion incidence calculation was performed individually, respecting the practice time of each practitioner. The word “injury” was adopted as any pain or injury that has impaired the life routine or modified the participant’s training sessions [7, 22]. Practitioners reported one “injury” at a time, and additional injuries were reported on separate forms. Questions related to the type of “injury” were addressed in order to indicate the mechanism (acute versus chronic). It is noteworthy that all of the answers were self-reported and the “injuries” were not confirmed by a medical diagnosis.

Injury rates

Injury rates were calculated by estimating the number of HIFT training hours in the preceding six months individually. The question asked, “How much time in hours did you spend doing HIFT in the last week?” was used in the estimate. Total weekly HIFT training hours reported were multiplied by 26, the number of weeks in six months. The rate was then converted to the number of injuries/1 000 training hours.

Statistical analyses

Continuous data were reported as mean and standard deviation, and the categorical data in absolute and relative frequency. Data normality was tested using the Kolmogorov-Smirnov test and asymmetry and kurtosis analysis (−1.96 to 1.96). Data that did not have their normality assumption accepted were submitted to logarithmic transformation. An independent sample t-test was used to compare the demographic characteristics of the participants according to injury status (injury versus no injury). The chi-squared test was used to verify the association of the independent variables (potential risks of injury) with the injury prevalence of the participants. A multivariate logistic regression model was used to verify the adjusted association and the odds ratio of the dependent variables in predicting the injury risk to participants. An inflation factor of the variance was used to avoid multicollinearity between the dependent variables in the model. A significance level of 5% (p < 0.05) was adopted and all analyses were performed using the Statistical Package for the Social Sciences (SPSS IBM®, New York, USA) version 20.0 software.

Results

The demographic characteristics of the participants are presented in Table 1. The prevalence of HIFT practitioners with an injury history related to the modality was 38.50%. The t-test for independent samples showed that there was no statistically significant difference between the injured and non-injured groups (p > 0.05) regarding the variables of age, height, and body mass. The frequency and duration of HIFT classes also did not differ between the groups (p > 0.05).

About 38.50% of the sample reported some type of injury caused by HIFT practice. Within this group, 70.7% of the participants suffered their first injury after starting HIFT. Table 2 presents the absolute and relative frequency data of the potential risks associated with the injury prevalence of HIFT practitioners. An ana-

Fig. 1 Anatomical diagram used to detail the injury location.
The analysis of the chi-squared test showed that only the HIFT practice time (Cramer’s v = 0.212) and competitive level (Cramer’s v = 0.217) were significantly associated with injury (p < 0.05). The data show that longer practice times in the modality and higher competitive levels (e.g., national competition level vs. non-participating) increased the injury risk.

The odds ratio for presenting a HIFT related-injury is shown in ▶ Table 3. The variables that entered the final multivariate logistic regression model were HIFT practice time (in months) and the competitive level. Thus, it was observed that the time the participant practiced the modality (p = 0.003, 1 – β = 93 %) and the competitive level (p = 0.038; 1 – β = 94 %) were significantly associated with the injury risk. The odds ratio for those HIFT practitioners with a practice time of more than two years was 3.77 times higher for “injury” when compared to subjects with a practice time fewer than six months. The odds ratio for those participating in national competitions was 5.69 times higher for “injury” when compared to non-competing subjects.

▶ Figure 2 shows the main causes of self-reported injuries (i.e., according to the participants) and their respective anatomical sites. The participants reported that the main causes of injury were performing incorrect execution technique of an exercise (35.4 %; CI95 % 28.98–41.82), repeated efforts (28.0 %; CI95 % 21.97–34.03), and exercises performed with high-loads (17.1 %; CI95 % 12.04–22.16). The most reported anatomical sites were the shoulder (36.6 %; CI95 % 30.13–43.07), lumbar area (19.5 %; CI95 %
The most commonly affected parts of the body were the shoulder, lumbar region and wrist.

The duration of the daily training session and the weekly frequency were recorded to calculate the training period of the participants over six months. These data were used to calculate the incidence of injuries for every 1 000 training hours. An injury incidence frequency of 7.1 per 1 000 training hours was identified. This study aimed to investigate the injury incidence in HIFT practitioners, in addition to identifying possible associated factors that may predict the occurrence of injury. Our data show that 38.50% of the sample had suffered some type of injury caused by the HIFT training routine, and about 70.7% of this group experienced their first injury only after initiating practice of this modality. An incidence of 7.1 injuries for every 1 000 hours of training was identified. In addition, it was verified that advanced subjects in the modality (>2 years) were 3.77 times (1–β = 93%) more likely to suffer an injury when compared with beginners (<6 months). When the analysis was performed regarding the competitive level, it was demonstrated that subjects who compete at the national level had a 5.69 fold higher injury rate (p = 0.038; 1–β = 94%) when compared with subjects who did not compete. The participants reported incorrect exercise execution technique, repetitive effort, and a high exercise load as the main causes of injury. The most commonly associated factors for injury incidence in practitioners and to estimate the injury frequency for every 1 000 hours of training. An injury incidence frequency of 7.1 was found for every 1 000 training hours.

### Discussion

This study aimed to investigate the injury incidence in HIFT practitioners, in addition to identifying possible associated factors that may predict the occurrence of injury. Our data show that 38.50% of the sample had suffered some type of injury caused by the HIFT training routine, and about 70.7% of this group experienced their first injury only after initiating practice of this modality. An incidence of 7.1 injuries for every 1 000 hours of training was identified. In addition, it was verified that advanced subjects in the modality (>2 years) were 3.77 times (p = 0.003; 1–β = 93%) more likely to present with an injury when compared with beginners (<6 months). When the analysis was performed regarding the competitive level, it was demonstrated that subjects who compete at the national level had a 5.69 fold higher injury rate (p = 0.038; 1–β = 94%) when compared with subjects who did not compete. The participants reported incorrect exercise execution technique, repetitive effort, and a high exercise load as the main causes of injury. The most commonly affected parts of the body were the shoulder, lumbar area, knee, and wrist.

The present study identified a significant association between practice time in HIFT and the competitive level with injury incidence in the regression model. Our data reveal that the most experienced subjects (≥2 years of practice) were 3.77 times (1–β = 93%) more likely to suffer injury than beginners (<6 months). It is possible that more experienced practitioners use higher workloads, undergo more extreme conditions, and consequently are more likely to suffer an injury [16]. Accordingly, Feito et al. [5] showed that participants with more than three years of practice had a higher prevalence of injuries (43.1%) when compared with participants with less than one year of practice (18.0%). In addition, Montalvo et al. [13] compared participants with and without injuries, and characterized the group with an injury history as having more experience in the modality (2.71 ± 1.82 vs. 1.80 ± 1.52) and with a higher training volume in hours/week (7.30 ± 6.98 vs. 4.85 ± 2.94). These data confirm the fact that there is a 5% prevalence of exercise addiction among HIFT practitioners, and this may be associated with counterproductive attitudes that can lead to negative consequences such as injuries [14].

The injury prevalence (Fig. 2) in the current study was similar to previous studies on HIFT practitioners [13, 15, 22]. Montalvo et al. [13] reported the shoulder (22.5%), knee (16.1%), and lumbar region (12%) as the most frequent body locations for injury, while Hak et al. [22] also identified the shoulder as the most reported injured location (31.8%), followed by the lower back (~38%). The shoulder and lower back appear to be the sites with the greatest predominance of HIFT injuries, possibly due to the movements commonly adopted in the modality (i.e. gymnastic and Olympic movements) [7], which implement an angulation beyond the healthy threshold [6]. This high injury frequency supposedly occurs due to the excessive volume of repetitions and overload in the shoulder region caused by Olympic movements used in HIFT that can also overload the lumbar region [7, 22]. Therefore, coaches...
should carefully monitor the training volumes, intensities and technique accuracy in these body regions.

The American College of Sports Medicine [12] has published a consensus on extreme conditioning programs (which includes HIFT), warning about its structure and listing the training induction of fatigue as a mechanism that can induce injuries in participants and may lead to incorrect execution of movements. In addition, it has been previously reported that high volumes and training intensities can provide high-injury prevalence in the shoulder and lumbar regions [7, 22]. We adopted injury as any pain or damage that has altered training sessions or resulted in a participant being unable to participate in the modality [7, 22]. It is noteworthy that there was an explanation of the term injury in the questionnaire to minimize different understandings, and the participants could contact the researchers whenever they had doubts. The incidence of injuries in the present study was higher (i.e. 7.1) than in previous studies (3.1, 2.1 and 2.3) for every 1,000 hours of training [13, 22, 23]. On the other hand, it is lower than in studies evaluating other exercise modalities (i.e. soccer) ~ 8 for every 1,000 hours of training) [24]. This fact may be in connection with the exponential growth in the number of HIFT practitioners [3] and response bias [25], which cannot be closely controlled despite the best efforts.

Therefore, coaches, sports scientists and other professionals in the field should be alert and ready to be involved in advising and correcting possible mechanisms related to increased risk of injuries. Although the reasons for the injuries are multifactorial, the sum of high overloads may predispose the risk of injury [26]. Thus, workloads (i.e. internal and external) addressed in training may provide important data to coaches to improve their training program prescription [27–29].

Although the results of this study are of great importance for coaches and sports scientists, some limitations need to be highlighted: (i) The number of injuries was obtained retrospectively through a questionnaire. This evaluation method highlights certain limitations, as participants may report inconsistent data on injury events within six months. However, it seems that this bias is minimized in regular weight training practitioners [20, 21]; (ii) Recruitment of participants took place by convenience, as a randomized sampling process proved impractical due to the exponential growth of training centers. Therefore, caution should be exercised in generalizing the results. On the other hand, it is essential to emphasize that our findings show important previous results about the causes, locations, prevalence and incidence of injuries in the participants.

From a practical perspective, these results may help in prescribing interventions in order to reduce the likelihood of injuries occurring in HIFT participants due to a better understanding of the mechanisms and anatomical distribution of the injuries. As a result, these findings provide a basis for coaches and sports scientists regarding orientation of the movement technique through structuring the training of their practitioners, indicating thus that greater caution is necessary for creating strategies for the movement to be carried out in a satisfactory way, choosing quality rather than quantity. In addition, dedication to injury prevention strategies may favor lower recurrence rates and absence from training sessions, which in turn may result in substantial reductions in injury costs as a result.

Conclusion
It is possible to conclude that the injury incidence in the present study was 7.1 for every 1,000 training hours and the majority of the injuries affected the shoulder, lumbar area, knee and wrist. In addition, the most reported injury causes were incorrect execution techniques, recurrent efforts, and high-loads. Moreover, participants at the advanced level (>2 years) were 3.77 times more likely to have injuries compared to beginners (<6 months). Finally, it was also found that subjects who compete at the national level present a 5.69 times greater chance of injury when compared with subjects who do not compete.

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Conflict of Interest
The authors declare no conflict of interest.

References


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