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Monitoring of sport participation and injury risk in young athletes

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ABSTRACT

Objectives: Careful modulation of training characteristics in high-level sports optimizes performance and avoids inappropriate workloads and associated sports injury risk. The aims of this study were to compare sport participation characteristics in different youth sport categories and to investigate their relationship with injury.
Design: Prospective cohort follow-up.
Methods: Young (12–19 years) high-level athletes ($n = 154$) from a regional sport school were followed during 41 weeks regarding sport participation characteristics and traumatic and overuse sports injuries (time-loss definition). All data were self-recorded by the athletes in an electronic system "TIPPS" (Training and Injury Prevention Platform for Sports) and subject to a systematic data quality control. Volume and intensity (self-rated perceived exertion) of each sport session were used to compute weekly load, monotony and strain. Sport categories were defined as team, racket, and individual sports.
Results: All sport participation characteristics were dependent on sport category ($p < 0.05$). Weekly intensity, load and strain were dependent on age ($p < 0.05$). Racket and individual sports were associated with lower injury risk (HR = 0.37 and 0.34, $p = 0.001$ and $p < 0.001$, respectively) compared to team sports. Average sport participation characteristics were not related to injury according to the survival analysis. However, intensity during the week prior to injury was significantly higher ($p < 0.01$) compared to that of the 4 preceding weeks.
Conclusions: This study investigated for the first time the relationship between sport participation pattern and injury risk in young athletes. The monitoring method was sensitive to variations according to pertinent variables and might help identify athletes with increased sports injury risk.

1. Introduction

Improvement in athletic performance is highly correlated to the training load of the athlete[1,2] and to the alternation between periods of intense and light training.[3–5] Indeed, sport participation characteristics in high-level sports require careful modulation of both training volume and intensity, in the short term and the long term, to help athletes reach their highest performance level.[6] Monitoring of training load is fundamental for trainers to fine-tune the athlete's daily program.[7] Although periodization of training should be quantifiable, there is no single indicator or methodology applicable to different training types. Endurance athletes generally use volume as the main outcome, but this does not account for training intensity. Similarly, the latter aspect also deserves attention in sports characterized by high demands in strength and power.

A feasible and well-accepted method is the recording of self-reported rating of the overall workout intensity, called session rating of perceived exertion (RPE), using the Borg scale.[8] Training load is subsequently determined by multiplying session intensity by its duration, expressed in arbitrary units. This method was originally proposed by Foster and co-workers[2,8,9] who concluded that it was a valid method to quantify sport participation in a wide variety of exercise types. Significant correlations have recently been reported between this approach and objective measurements of training intensity in individual high-intensity disciplines,[10,11] in endurance sports[12] and in team sports.[13–15]

This method could be helpful to monitor sport participation characteristics (e.g. volume and intensity of training and competition) in the field of competitive youth sport. Indeed, many disciplines are characterized by increasingly early specialization, combined with an ever growing training load.[16,17] As a consequence, young athletes encounter many sports-related injuries when practicing at a high level. As previously suggested,[16–18] inappropriate training load and scheduling could be risk factors for sports injuries. Applying the session RPE method in youth sport could therefore provide an opportunity to analyze training load more precisely and to study the relationship between specific characteristics of sport participation and sports injuries.

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Therefore, the primary aim of this study was to compare, for the first time, sport participation characteristics of different sport categories in youth sport as evaluated by self-reported rating of overall working intensity and training volume. We hypothesized that sport participation characteristics would be different in team, racket and individual sports. A secondary hypothesis was that sport participation characteristics would be related to injuries.

2. Methods

This prospective cohort study focused on 269 young elite athletes (12–19 years) enrolled in a regional sport school and followed for 41 weeks (from the 20th of September until the 1st of July). The sport school provides a typical high school curriculum but proposes an adapted time schedule permitting two daily training sessions, some of which are organized within the school program. All pupils were athletes enrolled in the national training center of their respective sport federation and practiced at the highest national level. Some of them had been selected for international championships. Fifteen different sport disciplines were represented and grouped into 3 sport categories: team sports (basketball, handball, football, and volleyball), racket sports (badminton, tennis, and table tennis), and individual sports (athletics, canoe-kayak, cycling, gymnastics, judo, karate, swimming and triathlon). The latter classification is based on sport characteristics and specific injury risk.[19] To participate in the study, a written informed consent had to be provided by the parents or the athlete if 18 years or older. The study protocol had been previously approved by the National Ethics Committee of Research.

Athlete inclusion criteria were: (1) be enrolled in the sport school during the full school season, (2) be a member of the federal training center during the entire period of the follow-up and (3) comply with the data collection procedure (see below).

An internet-based electronic surveillance system (TIPPS, Training and Injury Prevention Platform for Sports) was implemented at the sport school to allow for easy recording of daily information by the athletes via personal access codes. Personal data recorded at baseline included age, sex, sport practiced and injury history over the past 12 months. Throughout the follow-up, the athletes uploaded volume, subjectively perceived intensity and context for each sport session on their TIPPS account. Subjectively perceived training intensity was evaluated on a 4-level scale consisting of 4 "smiley-icons" representing light, moderate, intense and very intense sessions.

Sports injuries, defined as a physical complaint resulting from a match or training that forces the athlete to interrupt or modify his/her usual training plan for at least one training unit (time-loss definition), were recorded by the athletes via a dedicated questionnaire on their TIPPS account, and classified based on the latest consensus on sports injury surveillance studies.[20–22]

Athletes were instructed to fill out their diary on a daily basis. Weekly appointments were made with every school class to improve study compliance. An athlete was considered compliant (3rd inclusion criteria, see above) if he/she had completed his/her personal sports diary for at least 80% of the observation period and doing so with a relative delay of no longer than 2 weeks to avoid recall bias. All uploaded data relative to sport participation were corroborated with regard to the schedule of the sport school and the respective sport federation. When uncertain information was identified, a direct verification was made with the athlete or, if necessary, the school staff and trainers to ensure the highest quality of data. Recorded information on sports injuries was systematically cross-checked and verified regarding completeness by a member of the investigating team, present daily on site. Active assistance was provided by the physical therapists responsible for the training of injured athletes at the sport school and the national trainers, which lead to a complete dataset for sports injuries, regardless of athlete compliance to data uploading.

Sport participation characteristics were determined following the methodology presented by Foster.[9] Total volume of sport practice (exposure time) was expressed in minutes. To be able to apply the session RPE methodology previously presented[8,9] to our data set, we attributed the following, corresponding values from the Borg CR-10 scale (arbitrary unit) to each smiley icon: light = 2, moderate = 4, intense = 7 and very intense = 9. The product of session intensity thus determined and session volume was defined as session load. The sessions of each day were added-up to provide *daily training load* and, similarly, the sessions of each week were summated to obtain *weekly training load*. Mean daily load and the standard deviation (SD) were calculated for each week. The *monotony* of each week was computed by dividing the mean daily load by the standard deviation of the training load of that week. The *weekly strain* was determined as the product of weekly training load and monotony.

Weekly sport participation characteristics were averaged over the period from the beginning of the follow-up until the first injury or the end of the observation period (= period of interest). The effect of sport category on sport participation characteristics was tested using analyses of covariance (ANCOVA), controlling for sex and age. Injury incidence was defined as the number of sports injuries per 1000 h of exposure (training and competition). Two different approaches were used to study the relationship between sport participation characteristics and injury occurrence. Firstly, a Cox proportional hazards regression (backward LR method) was used to identify injury risk factors amongst the average characteristics of sport participation over the period of interest. Only weekly volume and intensity of sport participation were used in the model, since the other variables are calculated based on the preceding ones. Exposure volume to sports (hours) until injury occurrence (event of interest) or the end of the observation period was used as the outcome variable. Secondly, the short-term changes of sport participation characteristics of injured athletes during the period preceding the injury were investigated by comparing the data of the week just prior to injury (W_{-1}) with the mean values of sport participation characteristics of the preceding 4 weeks (W_{-2}–W_{-5}), using a repeated measures analysis of variance. Values are presented as mean ± SD. Significance was accepted for $p < 0.05$.

3. Results

From the 269 young athletes enrolled at the sport school, 154 athletes (57%) met our inclusion criteria. Compliant and the non-compliant subgroups were similar regarding the proportion of injured athletes (66.3 and 68.8%, respectively), as well as sex distribution and sport categories represented.

All data presented hereafter are from the subsample of compliant athletes. On average, athletes were 14.1 years old, males accounted for 64.9%, and the proportion of athletes engaged in team, racket and individual sports were 45.5, 16.9 and 37.7%, respectively.

Fig. 1 illustrates the weekly load of sport participation according to sport category. Weekly load showed periodic variations throughout the observation period with easily identifiable decreases during holidays (weeks 7, 14–15, 22, 31–32 and 36). Additionally, sport categories were characterized by largely distinct weekly loads.

Table 1 provides the mean (±SD) values of sport participation characteristics according to sport category, sex or age category. It should be noted, however, that age was used as a continuous variable in the ANCOVA model. Significant differences between sport categories were observed for all variables. Additionally, weekly