Universidade de Lisboa
Faculdade de Motricidade Humana

INJURY PROFILE IN CHILDREN AND ADOLESCENTS (10 TO 18 YEARS) ACCORDING TO THEIR BIOLOGICAL AGE AND LEVEL OF SPORTS PARTICIPATION

Lara Raquel Pimentel Costa e Silva

Orientador: Doutora Maria Isabel Januário Fragoso

Tese especialmente elaborada para obtenção do grau de Doutor em Ciências da Motricidade ramo de Reabilitação

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Abstract

Physical activity (PA) is beneficial, enhancing healthy development. However, participation in PA involves a risk of injury that has a considerable public health impact. There are physical and physiological differences between children and adults related to growth and development that may cause children to be more vulnerable to injury. This means that the demands of sports practice can overlap with growth and maturation, creating a favorable environment for injury occurrence. The present dissertation presents five articles that study sports injuries in Portuguese children and adolescents and its association with predictors such as maturation, decimal age, PA level (defined by type and volume of PA), intensity of PA, health related quality of life (HRQoL) and parental instruction, variables poorly studied in this context. In the first study, the extent of the problem was determined. Injury prevalence of and its profile was set, and the first approach to risk factors was done. The results were expressive and comparable to those recorded in European countries and in the United States of America. They were mostly benign conditions but the severity and residual effects were already significant. The injury occurrence increased with age and was higher in federated athletes and school sports. The second and third studies determined the influence of decimal age, maturation and PA level on injury occurrence, injury rate, injury type and body area injury location in both sexes. The results showed that all PA levels influence injury occurence and its profile. Maturation was a strong injury predictor, especially in girls. We also concluded that chronological age may not be an absolute indicator for injury risk at this specific stage. Maturation assessment appears to be a more accurate indicator. Study four replicated the model presented in study two and three, but instead of considering PA level, considered PA intensity. The results showed that PA intensity is also an injury predictor, with expression over injury profile. Study five explored the effects of biossocial variables – HRQoL and parental instruction. Results showed that three dimensions of KIDSCREEEN-52 and the level of parental instruction are associated with injury and its profile. The present work provided evidence that injury etiology in Portuguese children and adolescents is multifactorial, being associated with maturational, biosocial and load variables (type, volume and intensity of PA). These data may be relevant for injury risk stratification at this specific stage of growth. It may also provide indicators to consider the different levels and intensities of PA, thus contributing to the prevention of injuries.

Key words: Sports Injuries, Children and Adolescents, Physical Activity, Maturation,

Resumo

A actividade física (AF) praticada por crianças e adolescentes é benéfica, promovendo um desenvolvimento saudável. No entanto, neste grupo etário, ocorrem uma série de lesões associadas à prática das actividades desportivas, com consequências significativas na saúde e qualidade de vida. Existem diferenças fisiológicas consideráveis entre crianças e jovens e adultos que podem tornar os primeiros mais vulneráveis a lesões. Estas diferenças relacionam-se sobretudo com o crescimento e desenvolvimento psicossocial presente nesta fase. Isto significa então, que as exigências da prática desportiva podem se sobrepor ao crescimento e maturação, criando um ambiente favorável para a ocorrência de lesões. A presente dissertação apresenta então cinco artigos que estudam a lesão em crianças e adolescentes portugueses e a sua associação a predictores como a maturação, idade decimal, nível de AF (definido pelo tipo e volume de AF), intensidade de AF, qualidade de vida e instrucção parental, variáveis poucas vezes estudadas neste contexto. Assim no primeiro estudo foi averiguada a extensão do problema, determinando a prevalência de lesão e seu perfil na amostra estudada, tendo sido realizada uma primeira abordagem aos factores de risco para a ocorrência de lesão. Os resultados encontrados foram expressivos e comparáveis aos registados em países europeus e Estados Unidos da América, e apesar de maioritariamente benignas, a severidade e os efeitos residuais destas lesões são já preocupantes. A ocorrência de lesões aumentou com a idade e foi superior nos atletas federados e de desporto escolar. O segundo e terceiro estudos determinaram a influência da idade decimal, maturação e nível de AF na ocorrência e taxa de lesão e tipo e localização anatómica da lesão, em ambos os sexos. Os resultados mostraram que todos os níveis de AF são influentes na lesão e perfil de lesão e que a maturação foi um predictor para a lesão, sobretudo no sexo feminino. Concluímos também que a idade cronológica pode não ser um indicador absoluto para o risco de lesão nesta fase específica, sendo a avaliação da maturação uma medida mais precisa. O estudo quatro reproduziu o modelo apresentado no estudo dois e três, mas em vez de considerar o nível de AF, considerou a intensidade de AF. Os resultados obtidos mostraram-nos que a intensidade de AF é também predictora de lesão em ambos os sexos, expressando-se de várias formas sobre a lesão. O estudo cinco, estudou os efeitos das variáveis de natureza biossocial nomeadamente qualidade de vida e instrucção parental, onde pudemos concluir que três dimensões do KIDSCREEEN-52 e o nível de instrucção parental estão associados à lesão e seu perfil. O presente trabalho fornece então evidência que a etiologia da lesão e seu perfil em crianças e adolescentes portugueses é multifactorial, estando associada a variáveis maturacionais, biossociais e de carga (tipo, volume e intensidade de AF). Estes dados podem ser relevantes para uma melhor estratificação de risco nesta fase específica de crescimento; mas também quando consideramos diferentes níveis e intensidades de AF, contribuindo deste modo para a prevenção de lesões.

Palavras chave: *Lesões Desportivas, Crianças e Adolescentes, Actividade Física, Maturação*

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Abbreviations

PA – Physical Activity

HRQoL – Health Related Quality of Life

PHV - Peak Height Velocity

SES - Socioeconomic Status

TEM - Technical Error of Measurement

TW3 - Tanner-Whitehouse III Method

MET - Metabolic Equivalent Task

MVPA - Moderate to Vigorous Physical Activity

QoL – Quality of Life

SEE – Standard Error of the Estimate

ISAK - International Society for the Advancement of Kinanthropometry

UAC - Upper Arm Circunference

TRI - Triceps Skinfold

UMA - Upper Arm Muscle Area

UFA - Upper Arm Fat Area

AAI - Arm Addiposity Index

OR – Odds Ratio

US – United States

MO – Maturity Offset

CI – Confidence Interval

SE – Standard Error

PE – Physical Education

CHAPTER 1

Introduction

It is generally agreed that physical activity (PA) is beneficial, enhancing healthy development in children and adolescents [3,8]. Promoting increased PA through participation in sports and recreational activities has become a major public health priority because of the rising rates of obesity and the increase of diseases related to sedentary lifestyle [5,12,13]. Despite the health benefits associated with children´s sports participation, this age group, incurs a variety of injuries while playing these sports and activities [9,11]. These injuries are the leading cause of pediatric injury burden [12] with a considerable public health impact [4,13]. Injuries have been identified as a significant barrier to participation in sports and recreation PA, and safety concerns are a factor in the decision to participate [5]. It is estimated that one third of school-age children that practice sport regularly will suffer from a serious injury [2]. These same injuries have specific characteristics with regard to sex, age, type, mechanisms and location [14] and may have residual effects and long term consequences on the musculoskeletal system, resulting in disfunction and subsequent reduction in levels of PA, counteracting the beneficial effects of sports participation [10]. A number of growth-related factors unique to adolescent age group play an important role in the epidemiology, types and management of these injuries. These mainly relate to the physical and psychosocial growth and development during adolescence. [9].

Sports growing popularity and its inclusion in more public school programs, compelled the scientific community to the study of injury problem associated with sport [15]. Current information on the epidemiology of pediatric sports injuries is needed [7]. The extent to which sport injuries impact children´s ongoing involvement in sport is also largely unknown [11]. A responsible public health policy requires that the potential risks as well as the benefits of increasing physical activity through sports participation be quantified [1]. The studies carried out have not been able to clearly identify children and adolescents who are at risk. The studied groups are not homogeneous, the level of PA is variable and the loads and intensities that athletes are exposed to are not quantified [6]. Few studies have produced information about the wider sporting community. Furthermore, it is known that injuries incurred at the community level of participation differ from those presented by elite players. It is important therefore to understand the incidence and nature of sports injuries at different levels of PA [1]. Most studies, are also based on the assumption that chronological age can be a good indicator of the biological characteristics of children and adolescents. So far, there aren´t studies that accurately quantify maturation and energy expenditure and demonstrate clearly what are the patterns and trends of injury in children and young people, belonging to different groups of well-defined sports participation.

So our main research goals were, in a first phase, to study the existing knowledge about childrens and adolescents' injury epidemiology, undestanding their particularities and main causes. It was also important to determine the extent of the sports injuries problem in Portuguese children and adolescents. For that purposes it was performed an extensive literature review considering this topic. Through the gathered information we were able to identify, select the most significant injuries variables and proceed to study one. Study one identified sports injuries prevalence and described injury profile. In a second phase some of the factors which played a part in the children/adolescents sports injuries equation were identified. For that goals, we performed four studies where it was analysed the influence of different sports injuries predictors on injury occurrence, injury rate, body area injury location and injury type. The selected predictors were chronological age, maturation (determined by bone age and maturity offset), PA variables (type, volume and intensity) and biosocial variables (parental instruction and Health Related Quality of Life – HRQoL). Study two determined the influence of chronological age, maturation and PA level on injury occurrence and injury rate. Study three also determined the influence of chronological age, maturation and PA level but on body area injury location and injury type. Study four was a smaller study that determined the influence of chronological age, maturation and PA intensity on injury occurrence, injury rate, body injury location and injury type. Study five determined the influence of HRQoL and parental instruction on injury occurrence, injury rate, body injury location and injury type.

The present dissertation is divided in nine chapters as described bellow and includes a compilation of five research articles published and submited to peer-review journals with an ISI Impact factor.

Chapter two presents a literature review about the topic, focusing mainly on sports injuries epidemiology and the studied predictors. Incorporates also a brief description of methodological issues related to sports injuries variables. This chapter corresponds mainly to a review which soon will be turned into a publishable article. Chapter three explains in detail the methodology employed through the performed studies. Chapter four to eight correspond to the five studies that were conducted to answer the research goals. A general and integrated discussion was conducted in chapter nine, where the main findings and conclusions of the five studies were synthesized and analyzed. The bibliographic references were included in the end of each chapter. The bibliographic references adopted were the American Medical Association sorted alphabetically.

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CHAPTER 2

Literature Review

2.1. Overview

The benefits of PA for children and youth are substantial. Sports participation are generally associated with both immediate and long term health and wellness benefits (emotional, social, spiritual, intellectual, and physical well-being) [8,29,34,74,89]. However, this heightened interest in sports contributed to an increase in pediatric sports-related injuries [8,23,29,44,45,62,71,80,88,91,97,99].They have become the primary cause of injury in young people [1,26,28,91,99,105]. Injuries have significant direct costs from evaluation, treatment, and rehabilitation and indirect costs of parental sick leave and lost productivity if parents miss work to attend to an injured child [1,13,25,42,66,96,99,104,105]. In addition to the immediate healthcare costs and school absence these injuries may have long term consequences on the musculoskeletal system, resulting in disfunction and subsequent reduction in levels of PA [1,20,21,26,36,38,62,85,91]. Injury may also disrupt potential benefits of sport, including community involvement, teamwork, mediation of social skills, self-esteem, relaxation and increased fitness [1,86]. Moreover, injured subjects experience negative phychological consequences, including mood disturbance and lowered self-esteem with a considerable impact on quality of life [86]. This condition is a serious concern for children/adolescents, parents, coaches and health professionals.

Participation in regular sports programs is then related to the occurrence of specific injuries. As in adults, these injuries also evolve to chronicity and may present concerning degrees of disability. However previous studies have shown that children and adolescents are not small adults in their response to exercise and stress [59,64]. There are physical and physiological differences between children and adults that may cause children to be more vulnerable to injury [2,75]. These mainly relate to growth and development during adolescence [76]. In addition promising young athletes are being exposed to high intensity training from an early age which is also related to injury [24,64]- Many of these youngsters initiate a specialization in their sports at a very early age [62]. As a consequence overuse injuries which are traditionally described in more mature athletes are now becoming recognized in pre-adolescents [20,24,44,71]. Sports injuries usually result from the combination of several risk factors interacting at a given time [78]. It is a multifactorial equation [78]. One of the most important challenges for the sports medicine community is to be able to differentiate the impact of the variables among different sports [78]. Each young athlete has individual risk factors and each sport/PA poses its own risk for injury [101]. Targeting the relevant groups and designing future research on the epidemiology of paediatric sports injuries is important [14,67]. Exposure, biological and sociocultural factors exert influence over several aspects of paediatric sport injury [88] as we will adress in the following sub-chapters.

2.2. Sports Injuries

To improve the comparability of sports injury epidemiology it's important to have consensus on definitional issues [60] . Agreement on the variables selected and methodologies applied are also priorities. The extent of sports injury problem is often described by injury incidence/prevalence. and injury rates. Indicators like severity, mechanisms, classification, body areas, type of injuries, consequences and costs of sports injuries are extremely relevant to establish the injury profile [67]. Afterwards the etiology of sports injuries needs to be identified [67] so that appropriate prevention measures can be designed and implemented.

Taking into account the available evidence on the subject, we considered and selected the following variables for the study.

2.2.1. Prevalence

It is estimated that more than 4 million children are injured annualy playing sports or participating in recreational activities [32,104]. Prevalence of children and adolescents sports injuries is high. In Europe countries like England and Germany reported values of nearly 40% of annual prevalence for the age group of 5-14 years and 11-17 years respectively [62,86,89]. Values of these magnitudes were also seen on other countries like Australia [16], and US [49]. Furthermore in the US, 20% of all emergency visits made by children aged 10-18 years were due to sports injuries [49]. This age group also presented the highest rate of sports related injury hospitalization [29].

2.2.2. Body Areas

As it is usually described in the literature the most commonly injured areas are lower and upper limbs. Children and adolescents who participate in recreational and organized sports are particularly susceptible to a broad spectrum of lower extremity injuries involving both the osseous and soft-tissue structures [40,92,104]. Fractures, strains and sprains particularly to the lower and upper extremities are prevalent injuries found in epidemiological studies [38,49,52,58,84,94,100,101,111]. Lower limbs injuries are often a result of strenght and flexibility deficits in the growing athlete [79,101] and reflects the greater exposure and involvement of the lower chain in physical activity (PA). Moreover the mechanical stress resultant from the upper body weight, makes the lower body more vulnerable to extra strain from PA [20,21]. Recent studies also have been confirming that injury area distibution differs significantly by age, with children more likely to be seen for boony upper extremity injuries and adolescents more likely to be seen for overuse lower extremity and spine injuries [20,22,101]. Knees, ankles, hands and wrists are the most referred body segments [2,21,26,27,35,37,58,59,102,108].

2.2.3. Type of Injuries

Half of the injuries sustained by young athletes result from sprains and strains [2,26,35,37,42,52,58,74,84,86,94,108] followed by fractures [18,32,92,102,111]. They are normally related with the specificities of the practiced sport [38,84] and may also reflect the growth velocity characteristics during adolescence. Traumatic bony injuries can occur more often in children/adolescents before Peak Height Velocity (PHV) and soft tissue injuries in adolescents after PHV [9,87,101].

2.2.4. Mechanisms

Injury is the result of two distinct biomechanisms. The first is the result of a single impact or force imposed to the structure, the second the end product of many repetitive minor insults. Trauma situations are the most meaningful mechanism of injury in children and adolescents [20,32,82,101]. However, literature is beginning to show a different pattern of injury. Recent studies are beginning to emphasize and describe overuse injuries as the most significant mechanism of injury at these ages [21,32,82,101]. Imbalance between loading and recovery time can lead to injury. This happens when repeated mechanical loading exceeds the remodeling capability of the structure under stress [31]. Moreover the increasingly highly competitive nature of youth sports increased periods of extensive training, sport specialization and participation in large numbers in competitive events makes overuse injuries a growing reality [3,32,50]. At this stage the immature musculoskeletal system is less able to cope with repetitive biomechanical stress [44,71]. Also overuse injuries tend to be underestimated because the definition of overuse injury is inconsistent [8,82]. Therefore injury mechanism definitions are extremely important. Acute injuries corresponded to injuries with an onset from a single, sudden and clear remembered event like direct and indirect trauma. Overuse injuries corresponded to injuries with a gradual onset, with no clear event identified, as a result of tissue repetitive and cumulative misuse or overuse [6,20,21,32,63,82,87,92,101].

2.2.5. Injuries Classification

Injury can be classified as a new injury, as a relapse injury or as a chronic injury. First time injury is considered to be the first occurrence/episode in a given structure/body area. Relapses as an injury of the same type at the same site, occurring after a subject's complete recovery from the index injury. Chronic injury is defined as an injury that kept symptoms without complete relief for a minimum period of three months [39,41,78]. Epidemiological data on injuries treatment suggest that repetition of injury is unlikely if treated adequately [103]. The study performed by Schroeder et al. [87] in the US, found that for a total of 2834 injuries, 79.9% were new and 19.1% relapses. However certain injuries such as sprains and strains tend to recur [79,90]. Individual biological characteristics and inapropriate treatment can predispose subjects to relapses [103]. Insufficient rehabilitation of the previous injury or failure to identify and correct the factors that led to the original injury may contribute to this pattern [31]. The care and rehabilitation of the initial injury constitutes an important aspect of injury prevention minimizing the risk of reinjury [78]. Professional evaluation of early injury patterns can provide focus for the development and evaluation of injury prevention strategies [78]. Moreover premature return to sport not only can increase the risk of reinjury but also can result in life-long consequences [80] An unknown proportion of these injuries are becoming chronic [80].

2.2.6. Severity and Consequences

The increase sports involvement of children from early ages and their enduring through growth, against their apparent vulnerability to injury, gives rise to concern about the risk, severity and long-term effects of injury [62]. Injury severity is defined as the time of absence from PA. Taking into account injury severity they are usually classified as minor when the subject lost from training/competition is inferior to 8 days; moderate when the subject lost is between 8 and 21 days, and major when the subject lost is superior to 21 days [41,68,78,87]. Literature reports that sports injuries in youth are mostly minor and benign [35,87,89] but nevertheless of great importance to both children and their families. They often cause pain and time lost from PA which can also bring social challenges at these ages [101]. It's also known that the pediatric athlete is able to return to full activity quicker than the adult because of a more rapid healing response [9,89]. Nonetheless severe injuries and unresolved and still symptomatic injuries increased over the past decades [27,46]. Residual effects and dysfunction associated to these injuries are a major [21,62,85,89]A sports injury can hamper PA for the rest of an adolescent life and might also influence mental health, attitudes towards sports and an active way of life [8,72,73,86].

2.2.7. Practice vs Competition

Whether injury risk is higher in practice or in competition is still a matter of some debate [38,55,86]. There are consistently more practices than games during the sport season and for this reason children can be more exposure to injury risk during pratice [80]. Furthermore, overuse injuries are also more likely to occur in practice than in games, as a consequence of the continued activity, particularly if there is insufficient time to recovery [83,87]. In addition, practices must simulate game conditions in order to prepare the players for competition, being natural for injuries to occur under practice conditions [78]. Nevertheless some results have shown a higher rate of injury in competition [3,27,52,55,102]. Games are usually full-roaster events, increasing injury risk [80]. Pressure to perform can play an important role. Multiple competitive events in the same day or over several consecutive days are also a risk factor for overuse injuries in young athletes [32].

2.3. Sports Injuries and Age

It is generally acepted that injury ocurrence increases with age [70,97]. Frequency of injuries in both females and males adolescents shows a direct relationship with increased age [50,102,108] approaching the prevalence rates seen in senior players [50,89]. Injury rates for both sexes normally peak around adolescence [61,69,88] and in Jayanthi and colleagues study [50], athletes who were injured had 1.67 times the odds of being older than 14 years when compared with uninjured athletes. Subjective intensity, training load, training volume, level of competition, injury risk taking, pressure to perform and sports specialization increases progressively with age [50,61,63,64]. Exposure to injury risk becomes higher [11,70]. However some authors are starting to recognize that the effect of age on injury risk at these ages may be trivial [11,35,70]. Sports injuries are related to growth itself. At this stage a dynamic and functional imbalance may predispose these individuals to injuries. Bone, muscle and connective tissue suffer significant changes, at different timings, which often causes unsuited structural and functional responses. So in young athletes, substantial increments in training occur during pubertal years that correspond to the period of maximal annual gains in stature and body mass. This means that the demands of the sport are superimposed on those of normal growth and maturation. It has been suggested that high training load overlapping maximal annual changes in growth increases the risk of sport injuries [70,92]. Also chronologic age isn't always a good development indicator [32] and probably not a good measure for categorizing children and adolescents in competitive levels. This situation can put two athletes in completely different maturational stages conditions to compete on equal terms. Interindividual variability in biological maturation probably corresponds to variation in readiness for sport and by inference in vulnerability to injuries [92].

2.4. Sports Injuries and Sex

Sex differences are often non-significant. Whether injury risk and patterns differ by sex is still a matter of some debate. The majority of studies indicate no significant differences between the overall injury rates in boys and girls [16,74,86]. However, the literature continues to reveal a slight tendency for males to be more often and severely injured in these ages [26,59,89]. These differences may just reflect the greater participation of boys in sport and active recreation, and their preference for high risk contact sports and their high level of sports activity [27,49,59,70,86,89,104]. Some studies also indicate that sex may be differentiator, with girls more likely to suffer from soft tissue injuries and boys more likely to suffer fractures [87,101]. Moreover sex is usually deeply related to the PA level, and PA level is associated to differences in injury prevalence and profile.

2.5. Sports Injuries and Maturation

Skeletal immaturity and the period of rapid growth may predispose the young athlete to certain sport-related injuries due to the inherent physiological process [6,11,23,71]Higher injury rates have been associated with periods of rapid growth [50,51,70,89] and maturation status seems to have an influence on injury characteristics [35]Quite clearly the pathogenesis of such injuries is linked to the unique and vulnerable phase of musculoskeletal development in adolescence [23,44]Growth spurt, maturity-associated variation, susceptility to growth plate injury and lack of complex motors skills needed for certain sports are among the risk factors that may play an important role in the growing athlete [2,62,71]. A certain set of conditions can generate an environment for injury being structural and tissue changes valuable contributions to this situation [7,9,44,62,69,71,76]. Issues like joint laxity/tightness, differential growth rates of bone and soft tissue, bone density and stiffness and muscle tendon imbalance can be significant contributors to injury as children progress throughout adolescence. Development and psychological immaturity must also be taken into account as intrinsic injury risk factors for this age group [80].

Growth cartilage in the immature skeleton is found at the growth plate. Biomechanical and clinical evidence suggests that growth cartilage, especially in the articular surface, is less resistant to repetitive microinjury and more vulnerable to stresses than mature adult counterpart [2,9,23,31,44,59,71]. At this stage growth plate is predominantly composed of metabolically active chondrocytes, rather than of extracellular matrix, which make it less resilient to traction and compression forces [50]. This makes the skeletally immature athlete more susceptible to overuse injuries [23,80]. They tend to be minor but may cause, if ignored, permanent alterations of bone growth with long-term disability as a consequence [6,24,80].

Growth itself poses a series of risks factors for athletic injury. Asynchronous development of bone and soft tissue provides significant additional risk to the adolescent [23,44]. The soft tissues do not follow the rapid longitudinal bone growth and elongate slowly and passively [44,69,71]. There is an increase in musculoskeletal thighness, loss of flexibility and enhanced environment for injury [89]. Tension develops across growth plates, apophyses, muscle-tendon units and joints. [50,69]. This can create an environment for traction apophysitis or apophyseal avulsion fracture [50] and acute and chronic joint-related injury [23]. However, this hypothesis remain controversial and some authors suggests that there is no flexibility loss during period of rapid growth [62,71] Also an imbalance between strenght and flexibility can happen, and structural laxity can also be present in children [23,54]. These changes put increased stress on the muscle-tendon junctions, bone-tendon junctions (apophyses), ligaments and growth cartilage. Those tissues are not immediately able to deal with the increased stress, resulting in a temporary imbalance between the load placed on these tissues and the capacity to deal with it. Especially in elite young athletes, where this imbalance is combined with intensive training this may increase susceptibility to overuse injuries [89,92].

During the growth spurt a dissociation between bone matrix formation and bone mineralisation occurs, leaving the bone weaker and more porous. Resistance to impact diminishes and the biomechanical properties of bone are temporarily altered [62,69,89,92]. Acute fracture risk is elevated during the adolescent growth [9,10,31,50,51,69]. Indeed the peak incidence of fractures occurs at the age of PHV [10,31,62]. Large epidemiological studies have found a high incidence of fracture, with 27% to 40% of girls and 42% to 51% of boys sustaining at least 1 fracture during their growth spurt. The highest incidence of fracture is observed in the forearm [10]. The difference of one more year in PHV increases by 40% the risk of upper limb fracture. This higher fracture incidence in late maturers is also associated with significant deficits in bone mass and strength [10]. Also in prepubertal girls who experienced later menarche, a reduced bone mineral density was observed before the onset of pubertal maturation. Later menarche is associated with impaired microstructural bone components and reduced mechanical resistance with increased risk of fracture by a factor of 2:1 [10].

Although after PHV, tissue and structural dynamic equilibrium begins to be reached some degree of fragility still persists, especially in soft tissues. “Adolescent awkwardness” is mentioned as a potential cause. Changes in the length, mass, and moment of inertia of the extremities and trunk had already occurred but muscles still have to reach their full size and strength [31]. The increases in strength needed to accommodate these changes may not occur in a uniform pattern putting increased stress on the joints [31,92]. Moreover adolescents need time to integrate body’s internal scheme [70]. This may lead to abnormal movement mechanics and a decline in performance on motor tasks during the interval of PHV. Possibly, this temporarily decline in essential motor performance during years of maximal growth contributes to an increase in traumatic injuries [70,92]. Also imbalances in growth and strength, coupled with the loading imparted by sport training and competition, create a situation conducive to the development of overuse injuries [4,31] reported that skeletally mature but muscularly weak boys were more susceptible to injury.

Children of the same chronological age may vary considerably in biological maturity status which influences measures of growth, performance and injury risk during childhood and adolescence [11,92]. The onset and timing of children and adolescents’ growth occurs with considerable variability in cohorts of the same chronological age [112]. In sports, juniors are commonly grouped according to their chronological age. It is estimated that about one third of all players of one age category are not within their normal maturity category [35]. Therefore, early and late maturing children and adolescents may not routinely be trained according to their biological needs [112]. There are definite structural, functional and performance advantages for early-maturers in sports requiring size, strenght and power. Heavier, faster players generate a larger impact force and the injury risk increases when unbalanced competition between early and late maturing subjects occurs [61,80,92,112]. Although not significant, injury incidence was found to be higher in early maturing as compared to late-maturing players. Early maturing players showed a higher number of tendinopathies, groin injuries, and reinjuries, whereas late-maturing boys had significantly more osteochondroses and a higher incidence of severe injuries leading to an increased injury-related lay-off time. However, aforementioned results need to be carefully interpretated since late-maturing boys can be underrepresented whereas early maturing boys overrepresented [35].

A factor that also contribute to this difference in vulnerability includes the suitability of the protective equipment [2]. During this stage, the protective equipment does not always fit and adjust to body proportions. Moreover, some subjects during growth may experience coordination, and balance decrease and a lack complex motor skills [69] Children may not have the complex motors skills needed for certain sports until after puberty [2] what may predispose them to falls, contact injuries and possible traumatic injuries. Sport skills, visual perception, eye-hand coordination are achieved through playing experience and physicall maturation.

Sports should as well be suitable for child's cognitive maturation stage. Young children with limited attention, who are distracted easily may not yet be capable of participating in highly structured programs. Child's developmental status may play a role in the risk for injury associated with the lack of understanding and motivation [31].

All these events acting singly or together make the immature musculoskeletal system less able to cope with trauma situations and repetitive biomechanical stress [44,71].

2.6. Sports Injuries and Physical Activity

There are limited studies evaluating sports injuries in skeletally immature young children, regarding different types and intensities of sports participation, however an epidemic of both acute and overuse injuries, has been reported [44].

2.6.1. Activity Type

Sports injuries occur across a range of activities including formal (competitive) and informal sport, school sport, active recreation sports, fitness activities and general PA [16]. Epidemiological reports of sports injuries confirm a high incidence of injuries occurring at all levels of sport participation, ranging in severity from cuts and bruises to spinal cord injury [93]. Injuries vary widely among sports [63,78] Each sport activity has its characteristic injury profile and degree of risk [17,70,78].

2.6.1.1. Federated

The increase of the number of children taking part in organised competitive sport has resulted in a epidemic of both acute and overuse sports injuries as children make the transition from a variety of free play movements to the specialised pattern of movements imposed by a single competitive sport [5]. Most sporting injuries occur during organized competition or practice as seen in federated sports [38,63]. Federated athletes train harder and longer and participate in sport throughout the whole year. As an undesired but inevitable consequence sports-related injuries increase significantly [70,89]. Federated athletes, associated with high intensity of training, high training volumes and high levels of sports participation present a higher risk of injury [50,70,84]. A 10-year follow-up suggests that injury incidence is significantly higher for athletes competing at an international level (87.5%) and at regional/country level (64.0%) compared with those competing at a national level (16.7%) or recreational level (47.1%) [51]. This pattern was also seen some years before in Maffulli and Baxter-Jones follow up [61]. Young athletes competing and succeeding at international level had significantly higher injury rates than those competing at club, regional/county, or national level, as a consequence of the intensity and duration of training necessary to compete at high level even at this age [61]. Traumatic injuries are common in organized body contact sports. But the minor and insignificant stresses which accumulate to produce overuse syndromes are more obviously linked to established sporting patterns. It has become clear, that the young athlete is at risk from microtrauma, which is sport specific [44]. Children who have not developed at least some level of strength, endurance and motor skills may be at increased injury risk as they begin participation in a specific sport [31]. However it is still not clear whether intensively trained young athletes are at greater risk of injury than children engaged in free-play activities [61]. Studies also report that elite athletes have lower injury rates than the general sporting populations [51] and at the same time it seems that appropriate and safe youth sports participation can provide a wide range of complementary health-enhancing benefits and gains in health related fitness compared to those achieved through other moderate to vigorous

PA outside organized sports (for example recreational exercise and free play) [8].

2.6.1.2. Recreative Sports

Spontaneous, unstructured activities and recreational sports may expose children and adolescents to the major forces of impact that can result in fractures and sprains [44]. These can happen in a variety of settings [38] and determine a significant part of the costs of the National Health Service [53]. However, it has been also proved that recreative sports present a low injury rate when compared to formal sports [107].

2.6.1.3. School Sports

With the growing popularity of sports and their inclusion in more public school programs, it becomes increasingly apparent that additional consideration must be given to the associated injury problem [109]. The existing data regarding the type, nature and frequency of high school sports injuries demonstrate that specific injury patterns occur [78]. Injury rates in high school athletes also have a direct relationship to exposure. More specialized athletes were more likely to be injured [32]. The severity of these injuries are usually minor, causing limited physical and social disruption, but a report identified such injuries as a major reason for unnecessary school absence [1]. Concerns about school sports have been raised particularly with regards to poor quality playing fields, inappropriate protective equipment and inefficient supervision by well-meaning but untrained people with limited knowledge of sports physiology and treatment of sports injuries [6].

2.6.2. Volume and Intensity

Although problems do not ordinarily arise at normal levels of activity, the more frequent and intense training and competition of young athletes may create conditions under which risk factors may exert their influence [61]. Young people are at particular risk because of the high levels of exposure at a time of major physiological change [1]. Early sports competition and specialization, combined with a growing body, crossing profound changes at physical, behavioral and cognitive level, and/or deprived of free play, can predispose the young child to sports injuries that may determine long-term dysfunction [50,63,101]. Injuries incidence is correlated with the weekly intensity, duration and load of training [63]. Recent studies have even point out the increase of sports participation, load and/or intensity prior to injury [43,63,95].

The rationale for intensive training, specialization, high performance and competitive sports in early to middle childhood is doubtful [12]. An emphasis on competitive success has become widespread. The spirit of the catch them young philosophy is tainted by the phychological and physical casualties which result from youngsters being pushed too hard and too soon [24,44]. Intensity of youth sports not only sacrifice fun but also produce injuries, burnout, social isolation, dropouts, premature retirement and may lead to reduced motor skill development [24,32,50,72,101]. If the cycle of sports specialization occurs too early in youth, motor skills and neuromuscular development will be impaired, which, in turn, increases the risk of injury and potentially reduces opportunities for the child to achieve optimal sport performance [6,51,73]. Nowadays, in many Western societies, youth sports participation has evolved from children recreational free play for enjoyment to adult driven, highly structured, deliberate practice devoted to sports specific skill development. Although studies suppport that some degree of sports specialization is necessary to achieve elite levels, there is some debate as to whether such intense practice time must begin during childhood and to the exclusion of other sports to maximize potential for success [6,24,50]. For most sports, there is still no evidence that intense training and specialization before puberty are necessary to maximise sports performance and there is a concern that these methodologies before adolescence may be harmful to a young athlete [24,50,73].

Given this trend toward early training, frequent competition and single sport specialization, it is no surprise that overuse injuries are common [32]. Studies have shown that injured athletes spent more hours per week in organized sports and had higher sports specialization scores [50]. Volume, intensity of training and long training sessions that require repetitive movements are correlated with overuse injury risk [31,87] along with increased risk of osteopenia and bone fracture [48]. A failure in incorporating scheduled rest periods within the training program is also an important factor [31].

The exercise load (frequency, intensity or duration), rest and recovery times and training expectations must be individualized and appropriate for the level of maturation, fitness, motivation, goals, time constraints and other conflicting demands of the child and adolescent. In general, increasing the duration or intensity of training more than 10% per week should be avoided [12,71,89]. The optimal levels of safe training should be continuously checked [12]. Focus in the adolescent years should be on development rather than results and competition. The drafting of clear guidelines set by multiple health organizations, designed to reduce injury rates, stated that intensive training of children has no physiological or educational justification, and claimed that diversity of movement and all-round physical conditioning should have priority over later specialization, advising that specialization in a single sport before adolescence should be discouraged, and age appropriate levels of competition should be respected [6,44,50,73]. Otherwise the health, fitness and performance related benefits of the additional training activities will be negated by disability, fatigue, injury frustration and resentment [8].

2.7. Sports Injuries and Biosocial Variables

There's still a lack of consensus on the relationship between biosocial variables and risk of injuries [110], but extensive consequences to several social dimensions are already recognized [1]. They cause significant school and sport disruption and have important implications for the wider family [1]. Sports injuries are normally minor, causing limited time lost from PA and social challenges, but recently such injuries were reported as a major reason for pain and mental health alterations [8,72,73,86,101].

2.7.1. Psychological Factors

Psychological issues may be an important factor in the occurrence of injuries in the sports-active child [71]. There is a clinical impression that the youngsters under psycological stress are more predisposed to injury and future musculoskeletal pain [30,71,103]. Injured athletes exhibit greater depression and anxiety and lower self-esteem than controls, immediately following a sport injury [96]. In addition, some specialized athletes may have low personal coping skills to deal with psychological aspects of the injury [72]. For many young athletes, pain and treatments are a way of life, bringing unintended consequences on children´s quality of life [101]. These factors may also be a predictor for futures injuries as competitive and aggressive sports participation continues [71,101].

2.7.2. Health Related Quality of Life

There are limited data about sports injuries and HRQoL. Recent and minor injuries don´t usually determine significant difference in HRQoL perception [65,66]. Most of the injured athletes are still participating in their sport to some extent, therefore limiting the effect of significant changes on the mental health subscales and total score of HRQoL, reflecting the high-functioning nature of these athletes and insensitivity to differences resulting from predominantly minor injuries. Nevertheless some studies already address lower HRQoL scores in adolescent athletes with self-reported injuries than in their uninjured peers across a wide age range [65,66].There is also clear evidence for the long-term effects of sport-related injuries [66].

2.7.3. Socioeconomic Status (SES)

Early reviews on SES clearly indicate that poor children had higher rate of injuries than non-poor children especially during childhood and adolescence [19,57] . Young people belonging to a low social class and living in deprived socioeconomic areas are consistently at greater risk than others [19,56,57,81,101]. The finding that injuries are more frequent among those of lower SES has been primarily based on analyses of injury mortality figures [110], so caution is needed when analysing this data. Socioeconomic gradients were often based on medical records relating to accidents and emergency departments visits, hospital admissions or recorded deaths. Recent studies have observed marked socioeconomic variation both in the circumstances in which injuries occur and in the extent and type of risk behaviours reported by adolescents, indicating differential rates of risk exposure [110]. However, SES is still apparently associated with increased risk of unintentional injury. On the other hand, other outcomes come across when considering the association between higher social class, and sports injuries [98,110]. Children living in families with higher incomes were more likely to suffer injuries related to organized sports [77,106]. This may be explained by the greater opportunities to participate in sports activities [77,106]. In contrast to this, children in families with lower incomes are rather limited since families spend less money on sports activities and engage itself in other leisure activities or non-organized sports [106]. Sprains and strains were also positively associated with higher family affluence. Higher levels of mother's education, family income, and health care coverage were also positively associated with reported injury rates [98].

2.7.4. Parental Instruction

Education seems to be a more relevant predictor of adolescent self-rated health status than income or SES compound indicator. Adolescents whose parents were more highly educated self-rated their health status better than adolescents whose parents have attained less formal education [15]. However children of more educated parents are normally more actively engaged in PA creating a higher risk exposure. Parental highest education level was associated with increased injury risk in Canada [33]. In Britain, young athletes' involvement in high level sport is heavily dependent on their parents. Parents with active lifestyle behaviours modulate these habits in their children [47]. In the present socio-economic and cultural situation, talented youngsters with less motivated parents, lower parental instruction or from a poorer economic background will be in disadvantage [5].

Besides the negative consequences associated with inactivity and long term dysfunction, health-related consequences associated with injury may have other, as yet unknown, sequelae that may affect areas of the adolescent's life, such as study habits, personal relationships, and risk for substance abuse [66].

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CHAPTER 3

Methodology

A brief description of the sample and study protocol will be provided in this chapter, however further specific methodological details will be provided in each study (Chapter 4 to 8).

3.1. Study Design and Sampling

The research protocol was in accordance with the Helsinki Declaration for scientific research involving human beings, and was approved by the Ethics Committee of the Faculty of Human Kinetics, University of Lisbon. Before inclusion in the study all subjects' guardians gave their written informed consent. All studies were of epidemiological nature. Five cross-sectional studies with analytical characteristics were performed. Table 1 summarizes the basic characteristics of each study regarding sampling.

Table 1 - Basic sampling characteristics of each study

Study	Sample	N	Sex	Age Range
1	Children and adolescentes attending four Lisbon high schools	651	343 boys 308 girls	10-18 years
2	Children and adolescentes attending four Lisbon high schools	647	340 boys 307 girls	10-17 years
3	Children and adolescentes attending four Lisbon high schools	651	343 boys 308 girls	10-18 years
4	Children and adolescentes attending four Lisbon high schools	121	57 boys 64 girls	10-18 years
5	Children and adolescentes attending four Lisbon high schools	651	342 boys 309 girls	10-18 years

3.2. Procedures

The work developed began with data collection that took place in three distinct phases:

1. Preparation of the data collection - during this phase the final adaptation of the questionnaire that evaluated sports injuries (LESADO) was carried out. This included the consultation of experts and a pre-test application. The remaining questionnaires that assessed SES, parental instruction and type and volume of PA (RAPIL II) and quality of life (KIDSCREEN-52) were also reviewed. The sequence of procedures of data collection was determined.

2. Initial contact with the participants - during this phase the schools were contacted. The schools that accepted to participate were: Quinta do Marquês secondary school, Delfim Santos preparatory and secondary school and Portela and Moscavide preparatory and secondary schools. With this geographical distribution over Lisbon district, we ensured a heterogeneous sample in terms of socioeconomic level. An informed consent was sent to the participant's parents. This document contained information on ethical and safety issues (X-ray protocol and anthropometric measures), as well as issues of non-monetary compensation and the possibility of quitting at any stage of the study. Within two to four weeks after sending informed consents were collected. In coordination with the schools, the data collection schedules were defined. All evaluations occurred during the hours of the Physical Education and Citizenship Education classes, during the 2nd and 3rd period of the respective academic year. The school years included were from the 5th to the 11th grade.

3. Data Collection - LESADO and KIDSCREEN-52 questionnaires were distributed and completed under the supervision of the research team (taking into account the characteristics of the sample and in order to lose the minimum information). The biosocial RAPIL II questionnaire was completed at home by the parents (taking into account the type of information requested, such as the degree of parental instruction or household income). At the same time, a team of eight certified ISAK anthropometrists (level two) was contacted. A preliminary study with 20

participants was carried out before data collection. The eight technicians evaluated a set of measures to be performed in the study. Intra-observer and inter-observer technical error of measurement (TEM) was defined. Four measuring stations were then created considering the lower intra and inter observer TEM of the anthropometrists. The study participants also performed the X-rays on the wrist to evaluate bone maturity. Sequentially, small groups of up to 16 students (number of acquired accelerometers) were organized. Instructions of accelerometers use and return were given to each group. A pre-study was also performed with the accelerometers. Five volunteer students of the School of Health Technology of Lisbon used them during a period of two days, with different configurations and registration frequencies in order to proceed with the configuration of the device that best served the aim of the investigation and the studied population.

After data collection, databases were built and organized into Excel and SPSS format files. Questionnaires, anthropometric data evaluation sheets and X-rays performed had an alphanumeric code assigned which identified each student. Anthropometric data was transformed into the typological body composition and proportional values. X-rays images were revealed and evaluated according to the Tanner-Whitehouse III method (TW3). PA records and questionnaires were also analyzed. Accelerometers continued to be applied until reaching the desired sample size. Only the students, who had maintained the same habits of PA were selected since this evaluation lasted one more academic year. This information was validated through the biossocial questionnaire and confirmed face-to-face. At this point another review and up-to-date bibliographical review was made and the process of creating and selecting variables started. This has proved to be of great importance in guiding the decision-making process on theoretical and methodological issues.

Final definitions of PA groups (federated sports, school sports, recreational sports and no sports participation), maturational variables (bone age, maturational level and maturity offset) and age groups to be studied (10-11 years, 12-13 years, 14-15 years and ≥ 16 years) were achieved. The selection of the first variables related to sports injuries to be addressed (injury occurrence, injury rate, body area location of the injury and injury type) was also selected.

After these important decisions, the statistical analysis and discussion of the results of the five studies presented proceeded.

3.3. Assessments

3.3.1. Injuries Measurements

In order to collect information about injuries it was used a self reported questionnaire (LESADO), adjusted and based on injury surveillance research and epidemiological questionnaires used in Portuguese sports samples [1,15,30]. The final questionnaire only included closed questions and was divided into four components: 1) personal data; 2) characterization of the PA; 3) characterization of training conditions and; 4) characterization of the sports injuries. It was provided a clear definition of injury based in current epidemiological research [4,18,45] and time frame used was six months (September 2011 to March 2012), as recommended in retrospective studies to prevent memory-related problems [14,37]. Injuries caractherization included questions about the amount of injuries suffered during the retrospective six month period, body area injury location (divided by body segments like head, shoulder, arm, elbow, forearm and so on), injury type (strains, sprains, fractures and others), situation in which the injury occurred (in training or competition), injury mechanism (direct trauma, indirect trauma, overuse), injury classification (first time injury, relapse, chronic), severity (downtime caused by injury) and injury consequences (fully recovered, not fully recovered, in treatments and/or with symptoms and / or conditioned activity). Taking into account the specificity of the sample and in order to make the questionnaire as clear as possible, some definitions have been included in some questions. Therefore injury mechanism definitions had the same guiding principles as those used by several authors [2,6,24,34,38,44]. Acute injuries corresponded to injuries with an onset from a single, sudden and clear remembered event like direct and indirect trauma. Overuse injuries corresponded to injuries with a gradual onset, with no clear event identified, as a result of tissue repetitive and cumulative misuse or overuse. For injury classification it was considered as first time injury the first occurrence/episode in a given structure/body area, relapses as an injury of the same type at the same site, occurring after a subject's complete recovery from the index injury and chronic injury as an injury that kept symptoms without complete relief for a minimum period of three months [13,31]. Injury severity was defined as the time of absence from PA. Taking into account injury severity they were also classified as minor when the subject lost from training/competition was inferior to eight days; moderate when the subject lost was between eight and 21 days, and major when the subject lost was superior to 21 days [13,26,31,38]. Injury rates were defined as the number of sports injuries per 1000 hours of exposure (training and competition) as also reported by several studies [3,15,24,40,41].

Valid and reliable information about injury on children can be obtained through a self-report survey [39]. It is widely accepted that children over 10 years of age can realiably and accuretaly self-report information and behaviours [7,39,49]. When children report their own injuries they are able to give a detailed account of the circumstances of the injury event [52]. Neverthless children under the age of 12 years may require assistance to complete the survey [39], because they can experience difficulties associated with literacy skills. To prevent bias and interpretation difficulties, all the subjects were followed, by the investigators, in completing the questionnaires. LESADO was filled by each subject in a quiet and comfortable space, prepared specifically for this purpose. It was required about 20 to 30 minutes to complete the questionnaire.

Injury data was assessed across all the studies presented in this dissertation.

3.3.2. Physical Activity Measurements

3.3.2.1. Physical Activity Level

The Biosocial Questionnaire RAPIL II was used to determine the participants PA level. Usually, large epidemiological studies are dependent on PA questionnaires [20] and the Portuguese biosocial questionnaire – RAPIL II has been used in several studies to measure biosocial variables like lifestyle of Portuguese samples [10,25,51]. This instrument provides a valid measure of time spent in PA by children and adolescents, reported by their parents [5].

These data allowed to create four PA groups. The no sports participation group, with no time spent in PA per week (except mandatory physical education classes), the recreative sports group with more than 90 minutes of PA per week being 60% of this volume of recreational activity; the school sports group with more than 90 minutes of PA per week being 60% of this volume of school sports activity and the federated sports group with more than 120 minutes of federated activity. In Portugal, federated sports players are also defined as those who have official recognition for their sport by a sanctioned sports association. These players usually have medical approval to participate and formal training/coaching. This classification allowed to include almost all of the initial participants; to built homogeneous and well characterized groups of PA and finally to assure that each subject belonged in a exclusive way to one PA group only.

This questionnaire was used in study one, two, three (chapter four, five and six) to provide information about PA level and as it will be explained ahead in study five to provide information about parental instruction (chapter eight).

3.3.2.2. Physical Activity Intensity

In Chapter seven all participants were attended to wear an ActiGraph GT3X activity monitor (Actigraph LLC, Fort Walton Beach, Florida, USA). It was worn around the waist, for five consecutive days (three weekdays and two weekend days). This device is a small accelerometer (3.8 × 3.7 × 1.8 cm), lightweight (27 g), which uses a piezoelectric acceleration sensor to collect motion data on three axes: vertical (Y), horizontal right-left (X) and horizontal front-back (Z). This data is filtered into signals of frequency in a rate of hertz, during an interval of time or epoch [19,50]. The epochs were defined into 1 second of time wear, lately converted into 5 seconds counts of activity, which are linearly related to the intensity of PA during those periods of time [35]. A valid day was defined as a day with more than 600 minutes of device wear, and non-wear periods were determined as more than 60 continuous zeros of activity counts [48]. Participants were only included in the study if they had at least three valid wear days. All participants were instructed to wear the accelerometer while they were awake and to take it off for any water activity (e.g. showering or swimming), if the device compromised the physical performance or its integrity (e.g. gymnastic or sports fight) and activity that involved cycling or rolling. During the aforementioned activities when the participants took off the accelerometer they were instructed to record in a diary [48]. The information registered in those diaries was coded by the time engaged in those activities multiplied by the Metabolic Equivalent Task (MET) estimated values according the Compendium

Energy Expenditure [33]. Those activities were included in the daily PA at the correspondent day, replacing the hourly assumed as unworn, and than added for the valid days [27].

The PA intensity level was classified according to moderate, vigorous or very vigorous intensity PA as proposed by Freedson [11]. The time encompassed in moderate and vigorous PA (MVPA) was determined [11]. Mean time per day at the different intensities levels was determined by summing all minutes spent in the count criteria and divided by the valid days. The defined cut-points proposed by Freedson equation [11] were 500-3999 counts for moderate intensity level, 4000-7599 counts for vigorous intensity level and 7600 or above counts for very vigorous intensity level.

Accelerometer measurements were performed for study four (chapter seven).

3.3.3. Health Related Quality of Life Measurements

To assess HRQoL, KIDSCREEN-52 was used. HRQoL is defined as the individual's perception of their position in life in the context of culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns [17]. This self-reported questionnaire is based on the definition of Quality of Life (QoL) as a multidimensional construct covering physical, emotional, mental, social and behavioural well-being and functioning components [8]. KIDSCREEN-52 is validated in 13 European countries, and is suitable for long term follow up measurement of HRQoL in children after injury since it meets the international quality standards [47]. It covers a large age range (8 to 18 years old), has good psychometric properties and covers the International Classification of Functionality content substantially [17]. An acceptable level of internal reliability for the Portuguese population (Cronbach's alpha = 0.80), was previously demonstrated [47]. The KIDSCREEN-52 is completed according to a Likert scale from 1 to 5 points and consists of a general index of HRQoL in ten dimensions: Physical Well Being, Psychological Well Being, Moods and Emotions, Self-Perception, Autonomy, Parent Relation and Home Life, Financial Resources, Social Support and Peers, School Environment and Social Acceptance and Bullying. Permission to use this questionnaire was granted by KIDSCREEN group. The scores of KIDSCREEN dimensions are based on the Rasch model in order to avoid participant's exclusion due to missing data. The scores of Rasch scales were calculated for each dimension, transformed into t-values, according to the mean values and standard deviations from a European multinational sampling [47].

KIDSCREEN-52 was also completed by each subject in a quiet and comfortable space, prepared specifically for this purpose, supervised by the principal investigator who followed and clarified all doubts, preventing the possibility of bias and interpretation difficulties associated with low literacy skills [29,39]. It was required about 20 minutes to complete the questionnaire. Children and adolescents are able to give a detailed account of lifestyle details [52] and have strong and reliable perceptions about their relative social standing [42]. School age is considered a milestone from which children are already able to understand and report reliable answers on the issues of HRQoL [32].

HRQoL measurements were used to perform study five (chapter eight).

3.3.4. Socioeconomic Status and Parental Instruction

As already addressed the Biosocial Questionnaire RAPIL II is a parent´s self-reported instrument and it was used among other information to measure biosocial variables. It has been used to collect personal, academic, socioeconomic and family-related information, as well as to evaluate daily PA habits of the subject [10,25,51].

Graffar Scale [16] is included in this questionnaire so the participants can be classified as it is proposed by this social index. To clarify the family or the participant socioeconomic status, Graffar Scale join together five social criteria: (1) parental occupation; (2) parental degree of instruction; (3) family income; (4) household characteristics (including type, number of rooms and features of the house); (5) location of family residence. Each of these variables get a final score ranging between 1 and 5 points being allocated level 1 to the most socially favourable position and level 5 to the most unfavourable. However, in this research, in order to facilitate the interpretation of data, all scores were reversed, with higher values being associated with higher socio-economic classes. It was also decided to use the arithmetic mean values for parents' occupation and level of education but every time the child lived with a single parent family, only the value of this family unit was considered. The final rating classified the subject according to the following references: I) Low Class - Families whose total points <8.5; II) Class Medium Low -

Families whose total points going from 8.5 to 12.4; III) Middle Class - Families whose total points will from 12.5 to 16.4; IV) Upper Middle Class - Families whose total points going from 16.5 to 20.4; V) Upper Class - Families whose total points ≥20.5.

Although we initially considered the socioeconomic level, we ended up using only parental instruction as biosocial variable in study five (chapter eight).

3.3.5. Maturation Measurements

Maturity measures consisted in determining maturity offset during adolescence (time before or after PHV according to Mirwald [28]) and in calculating bone age through radiographs (RX) of the left hand and wrist according to the TW3 [46]. X-rays were performed in a single session and thirteen bones ossification were evaluated. Maturity ratings were performed by one trained examiner without knowledge of the chronological age of the subjects. Maturity evaluation was independently replicated two weeks later by the same observer and the intra-observer technical TME was determined. An expert observer evaluated a random subsample of 37 X-rays and the inter-observer TME was determined. The intra-observer TME was .03 (.04) years and the inter-observer TME was .03 (.99) years.

In addition to bone age, the subjects were divided in three bone maturity categories: late maturers, when the bone age was inferior to the decimal age in over one year; normal maturers, when the difference between the bone and decimal ages was one year at the most; and early matures, when the bone age was superior to the decimal age in over one year [22,23].

Maturity offset was predicted from a specific equation for each sex (SEE equation is 0.592 for boys and 0.569 for girls) based on Canadian and Belgian samples [28]. Can be used to classify adolescents as pre or post PHV and is also possible to group the individuals for years before or after PHV. Chronological age minus maturity offset provides an estimate of the age of PHV. Applicability of the method appears to be useful during the period of growth acceleration [3,9,21]. Chronological age was defined with the whole year as the midpoint of the range (e.g.,12 years include participants with 11.50 to 12.49 years of decimal age).

Maturation variables were assessed across all the studies presented in this dissertation.

3.3.6. Anthropometric Measurements

Anthropometric measures were collected according to the International Society for the Advancement of Kinanthropometry (ISAK) procedures. Anthropometric variables included: height (cm), body mass (kg), upper arm circunference (UAC - mm) and triceps skinfold (TRI - mm) used to determine muscle and fat arm area and to define the nutritional status of the participants. Measurements were performed by anthropometrists accredited by ISAK [43]. The technical error of measurement was lower than 5% for skinfolds and lower than 1% for the other measurements. The instruments were calibrated prior to use. All anthropometric measurements were obtained using portable measurement devices. Stature was measured using a portable Anthropometer (Anthropometric Kit Siber-Hegner Machines SA GPM, 2008) calibrated to the nearest 0.1 cm. Body mass was measured with subjects wearing light clothing and without shoes, to the nearest 0.5 kg, using a scale (Body Mass Scale Vogel & Halke – Germany – Secca model 761 7019009, 2006) calibrated with known weights. All girths were measured using a flexible tape (W606PM, Lufkin, USA), and the triceps skinfold was evaluated with a Slim Guide caliper (British Indicators Ltd .; Rosscraft; Creative Health Products) very reliable, having the same compression that Harpenden and allowing very similar readings [36].

Muscle and fat arm area were determined according to Frisancho references [12]. The equations used were: Upper arm muscle area (UMA-mm^2) = $(UAC-(\pi\times TRI))^2/(4\pi)$; Upper arm fat area (UFA-mm^2) =$(TRI\times(UAC/2)) - (\pi\times TRI^2)/4$ and Arm addiposity index (AAI) = $(UFA/UAC)\times100$.

Anthropometric measurements were performed for study one (chapter four).

3.4. Statistical Analysis

Data analyses were performed using IBM SPSS Statistics (SPSS Inc., an IBM Company, Chicago, Illinois, USA) version 22.0.

Descriptive statistics, including means and standard deviations, were performed in all five studies to determine the sample characteristics regarding the quantitative variables studied.

Additionally specific statistical analysis were included in each study according to the investigation purposes.

Study one determined sports injuries prevalence and described injury profile. Besides the descriptive statistics, study one performed a binary logistic regression to identify significant predictors of injury occurrence considering the total sample. As candidate predictors the variables sex, decimal age group, bone age group and PA level were considered. The backward stepwise method using the Wald statistic was applied for the model variable selection.

Study two determined the influence of chronological age, maturation and PA level on injury occurrence and injury rate. A binary logistic regression and gamma regression were used in order to identify significant predictors of injury occurrence and injury rate, respectively, for each sex. The set of candidate predictors included decimal age group, PA level, bone age, maturation level and maturity offset. The backward stepwise method using the Wald statistic was applied for the model variable selection for each sex and each regression model.

In study three the purpose was to identify injury type and body area location predictors considering the same candidate predictors used in study two. First, univariate analysis of each predictor was conducted: Chi-square tests of independence and Kruskal-Wallis tests were used for categorical and quantitative predictors, respectively. The set of candidate predictors for multinomial logistic regression consisted of all the variables that presented $p < .25$ in the univariate analysis, and a backward stepwise method using the likelihood ratio statistic was applied for the model variable selection.

In study four it was reproduced what had already been done in study two and three but instead of considering PA level it was considered PA intensity. The dependent variables were injury occurrence, injury rate, injury type and injury body area location, and the evaluated predictors were sex, PA intensity, decimal and bone age and maturity offset. The set of candidate predictors for multiple regressions consisted of all the variables that presented $p < .25$ in the univariate analysis and a backward stepwise method using the likelihood ratio statistic was applied for the model variable selection. Binary logistic regression was used in order to identify the significant predictors of injury body area location and multinomial logistic regression was used to identify the significant predictors of injury type.

In study five the influence of HRQoL and parental instruction on injury occurrence, injury rate, body injury location and injury type was determined. Chi-square test of homogeneity, t-test for independent samples, Kruskal-Wallis test and ANOVA were used to verify if there were significant differences between groups. Stepwise logistic, linear, and multinomial regression analyses were used to identify the significant predictors, among a set of biosocial variables. The evaluated predictors for each sex were parental instruction of each progenitor and HRQoL. The dependent variables were again injury occurrence, injury rate, and injury type and body area location.

The probability of $p \leq .05$ was considered to be significant for all analysis.

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CHAPTER 4

Prevalence and Injury Profile in Portuguese Children and Adolescents According to Their Level of Sports Participation

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Prevalence and Injury Profile in Portuguese Children and Adolescents According to Their Level of Sports Participation

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Abstract

Background: It's becoming increasingly apparent that sports can present danger in the form of injuries. The extent of this problem calls for preventive actions based on epidemiological research.

Methods: Two questionnaires (LESADO and RAPIL II) were distributed in four schools to 651 subjects aged between 10 and 18 years, involved in different levels of physical activity (PA) - recreative sports, school sports, federated sports and no sports participation (except physical education classes). Bone age was evaluated through TW3 method and anthropometric measures according to ISAK.

Results: 247 subjects (37.9%) reported a sports injury during the previous 6 months. The most injured body areas were lower limbs (53.8%), followed by upper limbs (29.0%) and the type of injuries found was strains (33.7%), sprains (27.1%) and fractures (23.1%). The most frequent causes were direct trauma (51.9%), indirect trauma (29.5%) and overuse (12.7%). A high percentage was relapses and chronic injuries (40.9%). The OR for age group ≥16 years was 2.26 suggesting that those ≥16 years were 2.26 times more likely to have an injury than the younger subjects and concerning the PA level, school and federated sports subjects were 4.21 and 4.44 times more likely to have an injury than no sports participation subjects.

Conclusion: Sports injuries in school age subjects were predominantly minor conditions where sprains and strains were the major injuries. They resulted mostly of trauma situations and lower

and upper limbs were the most affected areas. Injury occurrence increased with age and was higher in school and federated athletes.

Key Words: Injuries; Children and adolescents; Epidemiology; Bone Age

Introduction

The benefits of physical activity (PA) for children and adolescents are substantial [22]. Encouraging participation in sports and recreational activities has become a major public health priority because of the rising rates of obesity and diseases related to sedentary lifestyle. However, participation in PA involves a risk of injury that has a considerable public health impact [7]. It is becoming increasingly apparent that sports and PA can present a danger to health in the form of sports injuries [26]. In addition, to immediate healthcare costs, these injuries may have long term consequences on the musculoskeletal system, resulting in dysfunction and subsequent reduction of PA [16,22]. The extent of sports injury problem calls for preventive actions based on the results of epidemiological research. Current information on the epidemiology of paediatric sports injuries is needed, in a way that parents and coaches can be informed about the risks of injury in children's sports and about how they can help their children to avoid or limit these risks [22]. Also, increased knowledge about injury associated with specific PA exposures is an important part of an overall risk management strategy. So our aim was to determine the prevalence, demographic and injury profile in Portuguese youth from different levels of sports participation. We also aim to identify significant predictors of injury, including bone age, never studied in this context.

Materials and Methods

The research protocol was in accordance with the Helsinki Declaration for scientific research involving human beings, and was approved by the Ethics Committee of the Faculty of Human Kinetics, University of Lisbon (President – Pedro Teixeira; CEFMH Approval Number -

50/2015). Before inclusion in the study all subjects' guardians gave their written informed consent.

Given the nature of our goals and the diversity of the four PA groups studied, a survey study of epidemiological nature was performed with analytical, retrospective and transversal caractheristics. RAPIL II and LESADO questionnaires were distributed to 651 children and adolescents, aged between 10 and 18 years (age group corresponding to biological maturation), in four major schools, in order to collect information about PA level and injury prevalence and pattern, respectively .

RAPIL II was used to determine the biosocial profiling. Usually, large epidemiological studies are dependent on physical activity questionnaires [21] and the Portuguese biosocial questionnaire – RAPIL II has been used in several studies to measure biosocial variables like lifestyle of Portuguese samples [12,24,46]. This instrument provides a measure of parental report of their children's time spent in different type of activities, including PA. Using the information from this questionnaire the sample was divided into four PA groups. The no sports participation group, with no time spent in PA per week (except mandatory physical education classes), the recreative sports group with more than 90 minutes of PA per week being 60% of this volume of recreational activity; the school sports group with more than 90 minutes of PA per week being 60% of this volume of school sports activity and the federated sports group with more than 120 minutes of federated activity. This classification allowed to included almost all the initial sample; to built homogeneous and well caractherized groups of PA and; finally to assure that each subject belonged in a exclusive way to one PA group only.

LESADO is a self reported questionnaire that took about 30 minutes to complete and was developed after a critique review of the literature and of instruments used in similar studies [3,28]. The final questionnaire only included closed questions and was divided into four components composed by personal data, characterization of the PA performed, characterization of training conditions and characterization of the injuries. It was provided a clear definition of injury based on the definitions used in various sports injuries studies [4,23,26] and time frame used was six months (September 2011 to March 2012), preventing memory-related problems [16,33]. Injuries caractherization included questions about the amount of injuries suffered during the retrospective six month period, body area injury location (divided by body segments like head, shoulder, arm, elbow, forearm and so on), injury type (strains, sprains, fractures and others), situation in which the injury occurred (in training or competition), injury mechanism (direct trauma, indirect trauma, overuse), injury classification (first time injury, relapse, chronic), severity (downtime caused by injury) and injury consequences (fully recovered, not fully recovered, in treatments and/or with symptoms and / or conditioned activity). Taking into account the specificity of the sample and in order to make the questionnaire as clear as possible, some definitions have been included in some questions. Therefore injury mechanism definitions had the same guiding principles as those used by several authors [4,9,23,30,34,43]. Acute injuries corresponded to injuries with an onset from a single, sudden and clear remembered event like direct and indirect trauma. Overuse injuries corresponded to injuries with a gradual onset, with no clear event identified, as a result of tissue repetitive and cumulative misuse or overuse. For injury classification it was considered as first time injury the first occurrence/episode in a given structure/body area, relapses as an injury of the same type at the same site, occurring after a subject's complete recovery from the index injury and chronic injury as an injury that kept symptoms without complete relief for a minimum period of three months [15,29]. Injury severity was defined as the time of absence from PA. Taking into account injury severity they were also classified as minor when the subject lost from training/competition was inferior to 8 days; moderate when the subject lost was between 8 and 21 days, and major when the subject lost was superior to 21 days [15,26,29,34]. Surveys have shown to be useful for collecting children's injury and sport participation data [37]. However the use of self reported questionnaires, to evaluate injuries in children, may possible get unreliable information. In addition, children can also experience difficulties associated with literacy skills. Most of these technical problems, such as, bias and the interpretation difficulties can be prevented through a tight following when the survey is being completed [27,37]. All questionnaires were directly distributed by the evaluator who followed and clarified all doubts in filling.

Anthropometric measures were collected according to the International Society for the Advancement of Kinanthropometry (ISAK) procedures. Anthropometric variables included: height (cm), body mass (kg), upper arm circunference (UAC - mm) and triceps skinfold (TRI - mm) used to determine muscle and fat arm area and to define the nutritional status of the sample. Measurements were performed by anthropometrists accredited by ISAK [41]. The technical error of measurement was lower than 5% for skinfolds and lower than 1% for the other measurements. The instruments were calibrated prior to use. All anthropometric measurements were obtained using portable measurement devices. Stature was measured using a portable Anthropometer (Anthropometric Kit Siber-Hegner Machines SA GPM, 2008) calibrated to the nearest 0.1 cm. Body mass was measured with subjects wearing light clothing and without shoes, to the nearest 0.5 kg, using a scale (Body Mass Scale Vogel & Halke – Germany – Secca model 761 7019009, 2006) calibrated with known weights. All girths were measured using a flexible tape (W606PM, Lufkin, USA), and the triceps skinfold was evaluated with a Slime Guide caliper (British Indicators Ltd .; Rosscraft; Creative Health Products) very reliable, having the same compression that Harpenden and allowing very similar readings [32].

Muscle and fat arm area were determined according to Frisancho references [14]. The equations used were: Upper arm muscle area (UMA-mm^2) = $(UAC-(\pi\times TRI))^2/(4\pi)$; Upper arm fat area (UFA-mm^2) =$(TRI\times(UAC/2)) - (\pi\times TRI^2)/4$ and Arm addiposity index (AAI) = $(UFA/UAC)\times100$.

Maturity measures consisted in calculating the skeletal age obtained through radiographs of left hand and wrist of thirteen bones rated according to the Tanner-Whitehouse III Method (TW3) [45]. Bone age was evaluated by one skilled technician that has read more than 2000 X rays using this method.

Statistical analysis was performed using IBM SPSS Statistics, v. 22, and the significance level was set to 0.05. Descriptive statistics was used to determine prevalence and injury profile and binary logistic regression to identify significant predictors of injury (1 = yes, 0 = no). As candidate predictors the variables sex, decimal age group (0 = 10–11 years, 1 = 12–13 years, 2 = 14–15 years, 3 = ≥ 16 years), bone age group (0 = 8–9 years, 1 = 10–11 years, 2 = 12–13 years, 3 = 14–15 years, 4 = ≥ 16 years), and PA level (0 = no sports participation, 1 = recreative sports participation, 2 = school sports participation, 3 = federated sports participation) were considered. The backward stepwise method using the Wald statistic was applied for the model variable selection.

Results

Personal data

A total of 651 adolescents participated in this study, aged between 10 and 18 years (*Mean (M)* = 13.7; *Standard Deviation (SD)* = 1.8 years), being 343 boys (52.7%) and 308 girls (47.3%). The characteristics of the sample are shown in table I.

Table I reflects the distribution of boys and girls through different sports participation groups. There was a significant association between sex and PA level (Pearson chi-square test: $X^2(3) = 95.082$, $p < .001$); boys were more involved into federated sports, and girls were more involved in the no sport participation group and in school sports. Paired samples *t*-test showed that recreative ($t(175) = -2.023$, $p = .045$) and federated $t(216) = -3.184$, $p = .002$) athletes had lower mean bone age as comparing to decimal age reflecting a greater male participation in these groups. Kruskal-Wallis test revealed that there were marginally significant differences in the arm muscle area among PA levels (X2(3) = 6.636, p = .084). PA conditioned distribution of lean and fat mass. The federated athletes presented greater muscle area and the no sports participants lower muscle area. There was a significant association between injury and PA level (X2(3) = 62.039, p < .001). As injuries were concern, federated and school athletes presented more occurrences.

Table 1 - Sample characteristics concerning sex, bone and decimal age, height, weight, socioeconomic level, nutritional status and injuries, by PA level

	No sports participation	**Recreative Sports**	**School Sports**	**Federated Sports**
Sex				
Female	137 (44.5%)	87 (28.2%)	34 (11%)	50 (16.2%)
Male	76 (22.2%)	89 (25.9%)	9 (2.6%)	169 (49.3%)
Bone Age (years)	*M*=13.7 (sd=2.2)	*M*=13.4 (sd=2.4)	*M* =13.9 (sd=2.1)	*M*=13.5 (sd=2.4)
Decimal Age (years)	*M*=13.6 (sd=1.8)	*M*=13.6 (sd=2)	*M*=13.8 (sd=2)	*M*=13.8 (sd=1.7)
Height (cm)	*M*=157.8 (sd=10)	*M*=157.2 (sd=11.4)	*M*=158.2 (sd=9.8)	*M*=160.2 (sd=12.4)
Weight (Kg)	*M*=51.3 (sd=13.5)	*M*=49.8 (sd=13.4)	*M*=52.1 (sd=10.7)	*M*=52.2 (sd=13.2)
Socioeconomic Level				
Low	0 (0%)	0 (0%)	0 (0%)	1 (100%)
Below Average	7 (50%)	2 (14.3%)	1 (7,1%)	4 (28,6%)
Average	49 (42.2%)	28 (24.1%)	4 (3,4%)	35 (30.2%)
Above Average	41(24.3%)	53 (31.4%)	6 (3.6%)	69 (40.8%)
High	4 (20%)	8 (40%)	1 (5%)	7 (35%)
Nutritional Status				
Arm muscle Area (mm^2)	*M*=32.3 (sd=10)	*M*=32.5 (sd=9.8)	*M*=34.3 (sd=7.3)	*M*=35.1 (sd=10.4)
Low	19 (29.2%)	19 (29.2%)	2 (3.1%)	25 (38.5%)
Below Average	37 (35.9%)	34 (33%)	3 (2.9%)	29 (28.2%)
Healthy Range	138 (32.20%)	110 (25.8%)	32 (7.5%)	147 (34.4%)
Above Average	11 (28.9%)	9 (23.7%9	5 (13.2%)	13 (34.2%)
Excessive	8 (44.4%)	4 (22.2%)	1 (5.6%)	5 (27.8%)
Arm fat Area (mm^2)	*M*=17.4 (sd=9.2)	*M*=15.5 (sd=8.6)	*M*=17.2 (sd=7.6)	*M*=13.9 (sd=6.7)
Low	1 (14.3%)	4 (57.1%)	0 (0%)	2 (28.6%)
Below Average	11 (25.6%)	14 (32.6%)	0 (0%)	18 (41.9%)
Healthy Range	159 (32.4%)	129 (26.3%)	37 (7.6%)	165 (33.7%)
Above Average	23(36.5%)	16 (25.4%)	2 (3.2%)	22 (34.9%)
Excessive	19 (39.6%)	13 (27.1%)	4 (8.3%)	12 (25%)
Injury				
Yes	47 (19%)	54 (21.9%)	23 (9.3%)	123 (49.8%)
No	166 (41.1%)	122 (30.2%)	20 (5%)	96 (23.8%)

Characterization of the injuries

A total of 247 subjects, from the 651 that answered the questionnaire, reported experiencing a sports injury during the previous six months (37.9%). Considering the analysis by sex, 143 of 343 boys reported injury (41.7%) and 104 of 308 girls reported injury (33.8%). Among the children and adolescents that reported having injuries, 51.2% of the subjects only had one injury, but the remaining 48.8% had two or more injuries. The most injured body areas were lower limbs (53.8%), followed by upper limbs (29.0%). Torso and column accounted with 11.5% and head with 4.5%. As segments were concerned the most affected were wrist, hand and fingers (19.1%), knee (17.1%), leg (14.3%), ankle (14.2%) and lower back (6.5%). The type of injuries found was strains (33.7%), sprains (27.1%) and fractures (23.1%). The most frequent mechanism was direct trauma (51.9%), followed by indirect trauma (29.5%) and overuse (12.7%). A high percentage was relapses and chronic injuries (40.9%). The remaining occurrences were first time injuries (59.1%). The severity was evaluated by the downtime caused by injury: 54.6% saw their injury solved in less than a week, while the remaining 45.4% had to be away more than a week from their regular practice. Concerning the injuries consequences, 60.9% of the subjects were completely recovered, but 39.1% of the subjects still had symptoms, and / or conditioned activity, and/or still were doing treatments.

Injury Predictors

Using binary logistic regression, decimal age group and PA level were selected for the final model. Due to the significant association between sex and PA level ($X^2(3) = 95.082$, $p < .001$; illustrated in Figure 1), the variable sex, that was a significant predictor for injury in the preliminary univariate analysis, lost significance in the multiple logistic regression model.

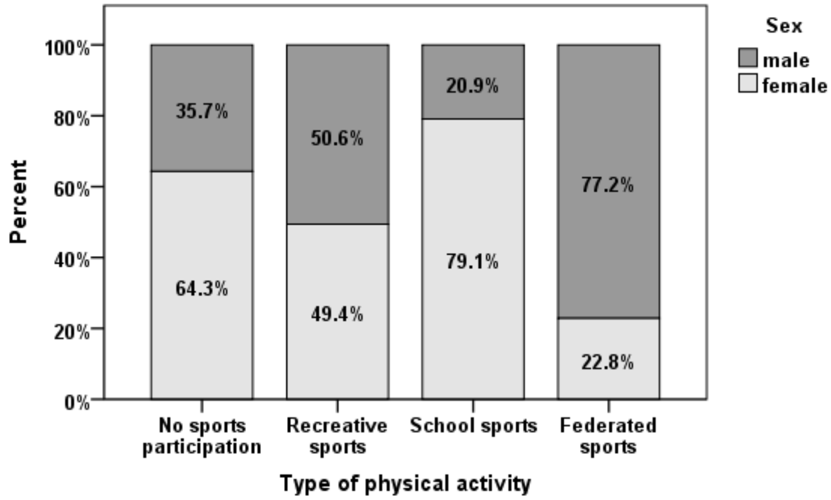

Figure 1 - Sex distribution in the four physical activity levels

The results of logistic regression model are shown in Table II. The OR for age group ≥ 16 years when compared with age group 10–11 was 2.26, indicating that, holding PA level constant, the older adolescents had 2.26 more chances to have an injury than the younger ones. The OR for school sports and federated sports groups when compared with no sports participation were 4.21 and 4.44, respectively; so, holding age group constant, those who perform school sports and federated sports had, respectively, 4.21 and 4.44 times more chances to have an injury than those who didn't't participate in sports activities.

Table 2 - Binary logistic regression model to predict the probability of injury

Predictor	*B* (Std. Error)	*p*	odds ratio	95% CI odds ratio
Intercept	−1.657(0.282)	<.001	0.19	
Decimal age group[a]		.039		
12-13 years(1)	0.346(0.285)	.225	1.41	(0.81, 2.47)
14-15 years (2)	0.365(0.282)	.194	1.44	(0.83, 2.50)
≥ 16 years (3)	0.814(0.303)	.007	2.26	(1.25, 4.09)
Type of physical activity[b]		<.001		
Recreative sports(1)	0.431(0.235)	.067	1.54	(0.97, 2.44)
School sports (2)	1.436(0.353)	<.001	4.21	(2.11, 8.40)
Federated sports (3)	1.491(0.216)	<.001	4.44	(2.91, 6.78)

[a] The reference group is 10–11 years.
[b] The reference group is no sports participation.
[c] Model $X^2(6) = 70.820$, $p < .001$; Hosmer & Lemeshow $X^2(6) = 2.436$, $p = .876$; Cox & Snell $R^2 = .103$; Nagelkerke $R^2 = .140$; Percentage of correct classification = 68%.

Discussion

The purpose of this study was to analyze sports injuries and assess its significant predictors in Portuguese children and adolescents from different groups of sports participation. Sports injuries in Portuguese school age children present considerable prevalence values. They were predominantly minor conditions, where sprains and strains were the major injuries registered; nevertheless, the severity and consequences of these injuries must be considered. They result mostly of trauma situations. Lower and upper limbs were the most affected areas. Injury occurrence increased with age and was higher in school sports group and federated sports group. Sex was deeply related to the PA level.

Prevalence

Recent data suggests that the risk of pediatric sports injury is high and constitutes a significant public health burden. Our results clearly point in this direction, presenting 37.9% of prevalence. Values of these magnitudes were already seen on other countries. In England children 5-14 years of age accounted for nearly 40% of all sports-related injuries [22], such as in Germany considering the age group 11-17 years [33]. In Australia the majority of the injuries occur between 10-19 year olds [5], and in the US peaked between the ages 13-15 years also representing 40% of all injury events [17]. Furthermore in the US, 20% of all emergency visits made by children aged 10-18 years were due to sports injuries [17]. This age group also presented the highest rate of sports related injury hospitalization [7]. A recent study estimated that more than 3.5 million children are injured annualy playing sports or participating in recreational activities [9]. This pattern was manifested more intensely in this age group because these ages comprehend the years of greatest sporting involvement, situation that fades when the subjects become adults [43]. Adulthood brings other responsibilities and tasks, often demobilizing subjects from a regular sport practice making them less exposed to these events. Adult athletes also demonstrate higher awareness for their bodies, with greater mastery of their patterns of movement and respect for their boundaries, which can decrease the risk of injury.

Body areas

The most commonly injured areas were lower (53.8%) and upper limbs (29.0%), as it is usually described in the literature. Fractures, strains and sprains particularly to the lower and upper extremities were common types of injuries found in epidemiological studies [2,11,17,19,31,42,43]. Body segments referred by our subjects also matched the available evidence. According to several authors [6,10,20,47], the most common sites of injury were knees and ankles, followed by hand and wrist [1,44]. This pattern reflects not only the representativeness of acute and traumatic injuries, but also the greater exposure and involvement of the lower chain in physical activities [13,39,48].

Type of injuries

As it is shown in our results, half of the injuries reported resulted from sprains and strains [20,27,39]. Like it was proven by several studies, strains and sprains were the most common injuries sustained by young athletes [1,10,16,19,31,47] followed by fractures [9,48]. They are normally related with the specificities of the practiced sport [11,31]. The traumatic nature of injuries found in our data can be a reflexion of the heterogeneous pattern of sports participation. These results can also reflect the type of injury associated to growth velocity during adolescence, where traumatic bony injuries can occur more often in children/adolescents before Peak Height Velocity (PHV), and soft tissue injuries in adolescents after PHV. This condition has to be studied in the near future.

Mechanisms

As we already address, our data pointed trauma situations as the most meaningful mechanism of injury (81.4%). Malisoux et al [23] also found similar data, being 34.8% of the injuries consequence of direct trauma, 42.0% related to indirect trauma and 23.2% a result of overuse. Several authors have founded similar patterns [19,20,44] however, literature is beginning to show a different pattern of injury. Recent studies are beginning to emphasize and describe overuse injuries as the most significant mechanism of injury at these ages. Stracciolini et al [43] reported, based on a cross-sectional data gathered during nine years, that 52.2% of all injuries were overuse and 47.9% were traumatic injuries. Difiori et al [9] also estimated the proportion of overuse injuries ranging between 45.9% and 54.0%. In the same year, Roos and Marshall [30] highlighted that overuse injuries tend to be underestimated because the definition of overuse injury is inconsistent. So, the increasingly highly competitive nature of youth sports increased periods of extensive training, sport specialization and participation in large numbers in competitive events [9], making overuse injuries a growing reality at these ages. In Portugal, the injury mechanisms do not yet reflect this pattern, however the studied sample included four levels of sports participation, and not merely the federated and elite sport, context where overuse injuries are more common.

Injuries Classification

Epidemiological data on injuries treatment suggest that repetition of injury is unlikely if treated adequately. However this is still undervalued in Portugal. There is a lack of follow-up and surveillance during PA practices and games by sports and health professionals, without adequate intervention in the majority of the cases. Typically, certain injuries such as sprains and strains tend to recur. Individual biological characteristics and inapropriate treatment can predispose subjects to relapses. The verified results (51.9% new, 25.0% relapses, 15.9% chronic) may indicate insufficient rehabilitation of the previous injury or a failure to identify and correct the factors that led to the original injury [8] and differ from the results reported by Schroeder, Comstock, Collins, Everhart, Flanigan and Best [34] who verified, in US high schools, a total of 2834 injuries, being 79.9% new and 19.1% relapses. It seems clear that measures must be taken in order to provide appropriate and adjusted treatment, at the right timing. This can clearly prevent early injuries to relapse or become chronic, which might compromise the sports future of children and adolescents, preventing them from benefiting from the practical advantages of PA.

Severity and Consequences

The increase sports involvement of children from early ages and their enduring through growth, against their apparent vulnerability to injury, gives rise to concern about the risk, severity and long-term effects of injury [22]. A recent study found that one-half of all overuse injuries resulted in a time loss inferior to one week, with few injuries causing the athlete to miss more than three weeks or resulting in medical disqualification [34]. It's also know that the pediatric athlete is able to return to full activity quicker than the adult because of a more rapid healing response. As we could see in our study, the majority of the injuries were also minor conditions, but also demonstrated a relevant percentage (39.1%) of residual effects and dysfunction associated to these injuries. Severe injuries and unresolved and still symptomatic injuries had increased over the past decade [6,25] what should be seen as a concern and warning sign of possible complications in the near future.

Age

As it is demonstrated in our study, the frequency of injuries in both females and males showed a unimodal relationship with increased age [47] approaching the prevalence rates seen in senior players [18]. Injury rates for both sexes normally peak around adolescence [22] and in Jayanthi and colleagues study [18], athletes who were injured had 1.67 times the odds of being older than 14 years when compared with uninjured athletes. Team-sports injuries also tend to have a peak in the middle teen years [35]. It's known that subjective intensity, training load, level of competition and sports specialization increases progressively with age [18,23], which can be one of the explanations for this phenomenon. Another cause can be related to the growth itself. At this stage a dynamic and functional imbalance might predispose these individuals to possible injury. Bone, muscle and connective tissue suffer significant changes in this period, at different times, which often causes unsuited structural and functional responses. Also chronological age isn't always a good development indicator [9] and probably not a good measure for categorizing children and adolescents in competitive levels, occasionally exposing them to noxious stimuli to their complex equation of dynamic equilibrium.

Activity Type

Epidemiological reports of sports injury confirm a high incidence of injuries occurring at all levels of sport participation [38]. Sports injuries happen across a range of activities including formal (competitive) and informal sport, school sport, active recreation, fitness activities, and general PA and it's recognized as a public health priority [5]. However, the higher injury incidence is normally related to sport category [23] as occurred in our study. School and federated sports presented higher risk of injury (OR 4.21 and 4.44, respectively) when compared with no sports participation. Sports injuries are normally related to organized competition and to practice, both at school and federated sports [11]. Despite school practice sessions are especially used for teaching skills [29], concerns about school sports have been raised in the past due to the poor quality of the playing fields, inappropriate protective equipment and inefficient supervision [4]. On the other hand, recent studies found that injury rates in school athletes have a direct relationship to exposure [9]. The emphasis given on competitive success has resulted in an increased pressure to begin high intensity training at early ages. In addition, more specialized athletes are more likely to be injured [9]. As a consequence, young athletes contract many sports-related injuries when practicing at a high level and when they undergo long training sessions. Recent studies clearly emphasize the increase of sports participation, load and/or intensity prior to injury [23,34], placing federated athletes in a higher risk of injury [9,31]. Another Portuguese reality is that technical and health teams are sometimes well meaning but untrained, with limited knowledge of sports physiology and treatment of sports injuries, what can clearly compromise athlete's integrity.

Sex

Sex differences are often non-significant as showed in our data. Whether injury risk and patterns differ by sex is still a matter of some debate. The majority of studies indicate no significant differences between the overall injury rates in boys and girls [5,27,33]. However, the literature continues to reveal a slight tendency for males to get more often and severely injured in these ages [36]. These differences may just reflect the greater participation of boys in sport and active recreation, and their preference for high risk contact sports and their high level of sports activity [17,33], as reported in our study. Sex is usually deeply related to the PA level, and PA level is associated to differences in injury prevalence as seen.

Conclusion

A large number of countries clearly established sport and recreation participation as a leading cause of pediatric injury burden [40]. This study proved that injuries are a relevant reality in Portuguese sport contexts, setting challenges for athletes, families, teachers and sports teams. The vast majority of these injuries proved to be benign, but a considerable percentage already expressed consequences in terms of dysfunction and residual effects. Athletes over 16 years and participating in school and federated sports revealed increased risk of injury occurrence. Ensuring safe athletic practices are necessary for children and adolescents to continue to receive benefits from PA. It's important to create prevention strategies that pass through the implementation and mechanization of practicable and feasible measures. A pre-participation exam should always be performed, at all levels of PA. This exam can screen a number of variables like stage of cognitive and physical maturation, developmental status, strength, endurance and motivation. All these factors help to understand who may need a more fundamental level of training and who is ready to a more advanced level. Certified coaches and teachers should have a deep knowledge of the different aspects of training, including duration, intensity, frequency, recovery periods and technique in order to avoid serious damage to the musculoskeletal system of athletic children [8,36]. Also monitoring training during the adolescent growth spurt is primordial and in some cases it may be appropriate to adapt training method. Suitable equipment, well maintained and fitted should be provided. Delaying single-sport specialization and allowing children and adolescents to experiment different activities to develop different skills and interests ought to be encouraged. It seems also relevant to investigate, in more detail, the influence of biological age versus decimal age and PA level as predictors of injury, in order to understand the influence and the contexts in which these variables can represent danger to youth.

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CHAPTER 5

Physical Activity-Related Injury Profile in Children and Adolescents According to Their Age, Maturation, and Level of Sports Participation

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Physical Activity Related Injury Profile in Children and Adolescents According to Their Age, Maturation and Level of Sports Participation

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Abstract

Background: Physical activity (PA) is beneficial, enhancing healthy development. However one third of school-age children practicing sport regularly suffer from an injury. These injuries are associated with gender, chronological age and PA level.

Purpose: Identify the importance of age, PA level and maturity as predictors of injury in Portuguese youth.

Study Design: Descriptive epidemiological study.

Level of Evidence: 3

Methods: Information about injury and PA level was assessed via two questionnaires (LESADO RAPIL II) from 647 subjects aged 10 to 17 years. Maturity offset according to Mirwald (time before or after peak height velocity - PHV) and Tanner-Whitehouse III bone age estimates were used to evaluate maturation. Binary logistic regression and gamma regression were used to determine significant predictors of injury and injury rate.

Results: Injury occurrence was higher for both sexes, in recreative, school and federated athletes. These injuries also increased with age in boys and in the higher maturity offset group, in girls. Injury rate was higher for both sexes in the no sports participation group. Early mature girls, with higher bone age and lower maturity offset showed higher injury rate.

Conclusions: Injuries in Portuguese youth were related to PA level, age and biological maturation. Recreative, school and federated athletes had more injuries ocurrences while no

sports participation subjects had higher injury risk. Older subjects had more injuries. Early mature girls, nearby PHV, may be particularly vulnerable to sport injury risk due to the growing process.

Clinical Relevance: Increased knowledge about injury with specific PA exposures data is important to an overall risk management strategy. This study has deepened the association between injury and biological maturation variables.

Key words: Injuries, Children and adolescents, Bone age, Peak Height Velocity, Physical Activity Level

Introduction

General reviews and analysis of trends in sports and physical activity (PA) demonstrate that active young people are more likely to show both immediate and long term health and wellness benefits [1,7,42]. These advantages help to promote PA and competitive sport by children and adolescents [7,17,20]. This heightened interest in PA has resulted in an increase in sport related injuries during practice and competitions [7,17,28,33]. Likewise over one third of school age children will sustain an injury severe enough to require treatment [1].

The pediatric age group incurs a variety of injuries in numerous sports with sex, age, mechanism, location, injury type and sport specific differences [42]. The majority of injuries are mild strains, sprains and contusions with few severe enough to require hospitalization and have a significant impact [16,20]. Injuries may lead to disfunction, reduced participation in sport and fitness activities, thus contributing to the childhood obesity epidemic, school absence,[15,20] and may disrupt potential benefits of sport [34]. Injury has direct costs from evaluation, treatment, and rehabilitation, and indirect costs with lost productivity if parents miss work to attend to an injured child [16]. In addition to the physical and financial costs, injured athletes experience negative phychological consequences including mood disturbance and lowered self-esteem [17]. Predisposing factors for injury include sport practice, morphological characteristics, age and gestural technique [17]. Children and adolescents are not small adults in their response to exercise and stress [25]. There are physical and physiological differences between children and adults related to growth and development that may cause children to be more vulnerable to injury [1]. Factors that may contribute to this difference in vulnerability include: the growth spurt; maturity-associated variation; imbalance between strenght and flexibility; structural laxity; bone, cartilage, joints and muscle-tendons stress vulnerability and; lack of motor and cognitive skills needed for certain sports until after puberty [1,9,20,37]. In addition promising young athletes are often exposed to high intensity training initiating specialization in their sports at a very early age [20]. Moreover, pressure to perform can play an important role on injury risk. These factors are associated with acute and chronic injury [25]. Thus, overuse injuries, which are traditionally described in more mature athletes, are now becoming recognized in adolescents [9,10,18]**.** The immature musculoskeletal system is less able to cope with repetitive biomechanical stress [28]. Demands of PA appear to overlap with growth and maturation [37] and as a result vulnerability for injuries can temporarily increase. Therefore it is desirable to identify the importance of age, PA level and maturity as predictors of injury in Portuguese children and adolescents.

Materials and Methods

The research protocol was in accordance with the Helsinki Declaration for scientific research involving human beings, and was approved by the Ethics Committee of the Faculty of Human Kinetics, University of Lisbon (President – Pedro Teixeira; CEFMH Approval Number - 50/2015). Before inclusion in the study all subjects' guardians gave their written informed consent.

Six-hundred and forty seven children and adolescents, of both genders, attending four major schools of Lisbon, aged between 10 and 17 years, involved in different groups of sports participation were selected.

In order to collect information about injuries it was used a self reported questionnaire (LESADO), adjusted and based on injury surveillance research and questionnaires used in epidemiological studies [2,17,32]. The final questionnaire was divided into four components composed by personal data, characterization of the PA, characterization of training conditions and characterization of the injuries. Injury was defined as any musculoskeletal condition or symptom that occurred as a result of participation in an organized practice, competition, or physical education class and which entailed at least one of the following consequences: (1) resulted in PA restriction for at least 24 h;

(2) Didn´t resulted in time lost from sports participation but determined changes in performance either in quantitative or qualitative terms or (3) required medical attention by an health professional [6,19,41]. Time frame used was 6 months (September 2011 to March 2012), as recommended in retrospective studies[15,34]. Valid and reliable information about injury on children can be obtained through a self-report survey [36]. It is widely accepted that children aged 10+ years can realiably and accuretaly self-report information and behaviours [11,36,43]. Neverthless children under the age of 12 years may require assistance to complete the survey [36], to prevent bias and interpretation difficulties, all the subjects were followed, by the investigator, in completing the questionnaires.

The Biosocial Questionnaire RAPIL II was used to determine the biosocial profile. Several investigations with Portuguese samples made use of this instrument [14,26,44]. It has been used to collect personal, academic, socioeconomic and family-related information, as well as to evaluate daily PA habits of the subject. The instrument provides a valid measure of time spent in PA, and it is also self-reported. These data allowed to create four PA groups. The no sports participation group, with no time spent in PA per week (except physical education classes participation), the recreative sports group with more than 90 minutes of PA per week being 60% of this volume of recreational activity; the school sports group with more than 90 minutes of PA per week being 60% of this volume of school sports activity and the federated sports group with more than 120 minutes of federated activity. In Portugal, federated sports players are also defined as those who have official recognition for their sport by a sanctioned sports association. These players usually have medical approval to participate and formal training/coaching .

Maturity measures determined maturity offset during adolescence (time before or after PHV, according to Mirwald [29]) and in calculating the bone age from radiographs of left hand and wrist. A random sample of 37 (5,7%) radiographs were assessed independently. The average difference between bone age independent evaluations, made two weeks after the initial assessments, was 0.02 ± 0.13 years and the intraobserver error for the replicated measurements was 0.03 ± 0.04 years. In addition to bone age, the subjects were divided in three bone maturity categories: late matures, when the bone age was inferior to the decimal age in over one year (%); normal matures, when the difference between the bone and decimal ages was one year at the most (%); and early matures, when the bone age was superior to the decimal age in over one year (%) [21,22].

Maturity offset (time before or after PHV) was predicted from a specific equation for sex (EPE equation is 0.592; 95% CI 18.1 years), based on the Canadian and Belgian males [29]. Maturity Offset minus chronological age provides an estimate of the age of PHV. Maturity offset can be used to classify adolescents as pre or post PHV and is also possible to group the individuals for years before or after PHV. Applicability of the method appears to be useful during the period of growth acceleration, between 12-15 years [23]. This study was limited to boys and girls between 10 and 17 years. Chronological age group was defined with the whole year as the midpoint of the range, i.e., 12 = 11.50–12.49.

Injury rates were defined as the number of sports injuries per 1000h of exposure (training and competition) as also reported by several studies [5,17,24,37,38].

The data was processed with a SPSS program. Binary logistic regression and gamma regression were used in order to identify some significant predictors of injury and injury rate respectively. The probability of $p \leq 0.05$ was considered to be significant for all analysis. For each sex, binary logistic regression model was adjusted for the dependent variable injury (1 = "yes", 0 = "no"), considering as candidate predictors age group (0 = "10-11 years", 1 = "12-13 years", 2 = "14-15 years", 3 = ">=16 years"), maturation level (0 = "late", 1 = "on time", 2 = "early"), type of physical activity (0 = "no sports participation", 1 = "recreative sports", 2 = "school sports", 3 = "federated sports"), bone age (in years), and Mirwald maturity offset (in years). The backward stepwise method using the Wald statistic was applied for the model variable selection procedure. Linear logistic regression used the same candidate predictors. The significant predictors of injury rate for each sex, log-normal and gamma regression models were considered, due to the positively skewed distribution of injury rates. The backward stepwise method using the Wald statistic was applied for the model variable selection procedure for each sex and each model. For each sex, the log-normal and gamma models were compared using the pseudo R-squared and the attained values let us to choose gamma models for both boys and girls: The gamma model was expressed by:

$Y_i = \exp\left(\beta_0 + \beta_1 x_{i1} + \cdots + \beta_k x_{ik}\right) \times \varepsilon_i$, where Y_i is the injury rate for subject i, β_0 is the intercept, and $\beta_1, \ldots, \beta_k$ are the coefficients associated to the predictors $x_1, \ldots, x_k$, respectively, and ε_i is the random error.

Results

The sample included 647 subjects, aged between 10 and 17 years (*M* = 13.7; *SD* = 1.8 years); being 340 boys (52.6%) and 307 girls (47.4%). A total of 247 subjects, reported a sports injury during the previous 6 months (37.9%; 95% CI: 34.2–41.7%). Considering the analysis by sex, 143 of 340 boys reported an injury (42.1%) and 104 of 307 girls reported an injury (33.9%). As regards to injury rate table 1 summarizes the data.

Table 1 - Injury rate by sex, age group and PA level

Injury Rate	Mean	Std. Deviation	Minimum	Maximum
Total	11.8	8.1	2.3	44.8
Sex				
Female	13.6	9.2	2.8	44.8
Male	10.4	6.9	2.3	44.8
Age Group				
9.5-11.5	14.4	6.8	3.1	29.6
11.5-13.5	10.9	8.1	2.3	44.8
13.5-15.5	11.4	8.3	2.3	44.8
>=15.5	12.1	8.4	2.8	44.8
PA Level				
No sports participation	21.9	10.3	14.9	44.8
Recreative	10.8	5.5	3.8	28.3
Scholar	12.6	4.7	6.9	21.7
Federated	8.1	4.7	2.3	34.5

<u>Boys – Predictors of Injury</u>

Age group and PA level were selected for the final model being significant predictors for injury (table 2). Boys who had recreative, school, and federated sports activities were, respectively, 1.325, 8.707 and 4.659 times more likely to have an injury than boys who were less active and only participated in physical education classes. However the results for the school sports group should be interpreted with caution because there were only nine boys classified in this PA category (which is evidenced by the low precision of the 95% CI for the odd ratio). Considering the age group, the odds ratio for 12-13, 14-15, and >= 16 years when compared with 10-11 years were 2.467, 2.149, and 3.296, respectively.

Girls – Predictors of Injury

PA level and maturity offset were alone in the final model (table 2). Girls who had recreative, school, and federated sports activities were, respectively, 1.742, 3.435 and 3.743 times more likely to have an injury than girls who were less active. Relatively to maturity offset, girls who had an offset value greater than or equal to 2.5 were 2.123 times more likely to have an injury than girls who had a maturity offset value inferior to 2.5.

Table 2 - Logistic regression models adjusted for the dependent variable injury (1=yes, 0=no) for boys and girls

Predictor	β (SE)	Wald	*df*	*p*	odds ratio	95% CI odds ratio
			Boys[1]			
Intercept	−2.057 (0.428)	23.098	1	<.001	0.128	
Age group		7.830	3	.050		
Age group (1)	0.903 (0.397)	5.164	1	.023	2.467	(1.132, 5.376)
Age group (2)	0.765 (0.395)	3.745	1	.053	2.149	(0.990, 4.664)
Age group (3)	1. 3 (0.436)	7.466	1	.006	3.296	(1.401, 7.753)
Physical activity		35.596	3	<.001		
Physical activity (1)	0.281 (0.375)	0.563	1	.453	1.325	(0.635, 2.764)
Physical activity (2)	2.164 (0.785)	7.595	1	.006	8.707	(1.868, 40.580)
Physical activity (3)	1.539 (0.325)	22.392	1	<.001	4.659	(2.463, 8.813)
			Girls[2]			
Intercept	−1.408 (0.220)	40.830	1	<.001	0.245	
Physical activity		18.057	3	<.001		
Physical activity (1)	0.555 (0.309)	3.226	1	.072	1.742	(0.951, 3.194)
Physical activity (2)	1.234 (0.404)	9.325	1	.002	3.435	(1.556, 7.584)
Physical activity (3)	1.320 (0.355)	13.853	1	<.001	3.743	(1.868, 7.499)
Mirwald_Dic_2.5	0.753 (0.289)	6.764	1	.009	2.123	(1.204, 3.743)

[1] Overall model evaluation (Likelihood ratio test), $\chi^2(6) = 47.861$, $p < .001$; Goodness-of-fit test (Hosmer & Lemeshow), $\chi^2(7) = 0.267$, $p = 1.0$; Cox & Snell $R^2 = .130$; Nagelkerke $R^2 = .175$; % correct classification = 67.9%.
[2] Overall model evaluation (Likelihood ratio test), $\chi^2(3) = 20.513$, $p < .001$; Goodness-of-fit test (Hosmer & Lemeshow), $\chi^2(2) = 0.000$, $p = 1.0$; Cox & Snell $R^2 = .064$; Nagelkerke $R^2 = .089$; % correct classification = 67.2%.

Boys – Predictors of Injury Rate

As injury rate was a concern, only PA level was included in the final model. Injury rate was higher in no sports participation group than in recreative (p < .001), school (p = .046) and federated (p < .001) groups (table 3).

Girls – Predictors of Injury Rate

The final model included PA level, Maturation level, Bone age, and Mirwald Maturation Offset (table 3). The injury rate was higher: (i) in the no sports participation group than in recreative (p < .001), school (p < .001) and federated (p < .001) groups, (ii) in early maturation group (p = .007) than late maturation group, (iii) in girls with higher bone age (p = .012) and lower Mirwald Maturation Offset (p = .033).

Table 3 - Gamma regression models adjusted for the dependent variable injury rate for boys and girls

Predictor	*B* (SE)	Wald	*df*	*p*	95% Wald CI
			Boys[1]		
Intercept	3.022 (0.126)	1441.164	1	<.001	(2.775, 3.268)
Physical activity		46.263	3	<.001	
Physical activity (1)	−0.626 (0.161)	15.124	1	<.001	(−0.941, −0.310)
Physical activity (2)	−0.479 (0.241)	3.964	1	.046	(−0.951, −0.007)
Physical activity (3)	−0.892 (0.126)	43.171	1	<.001	(−1.158, −0.626)
			Girls[2]		
Intercept	1.278 (0.794)	2.587	1	.108	
Physical activity		104.126	3	<.001	
Physical activity (1)	−0.748 (0.112)	44.816	1	<.001	(−0.967, −0.529)
Physical activity (2)	−0.606 (0.126)	23.078	1	<.001	(−0.854, −0.359)
Physical activity (3)	−1.139 (0.115)	98.311	1	<.001	(−1.364, −0.914)
Maturation level		7.475	2	.024	
Maturation level (1)	−0.386 (0.206)	3.499	1	.061	(−0.790, 0.018)
Maturation level (2)	−0.701 (0.262)	7.150	1	.007	(−1.215, −0.187)
Bone age	0.179 (0.072)	6.281	1	.012	(0.039, 0.320)
MirwaldMatOffset	−0.205 (0.096)	4.525	1	.033	(−0.393, −0. 160)

[1] Overall model evaluation (Likelihood ratio Chi-Square test): $\chi^2(3) = 46.710$, *p* < .001; Goodness-of-fit test (Pearson Chi-Square): $\chi^2(139) = 42.980$, *p* = .309; Pseudo R-squared = 0.235.

[2] Overall model evaluation (Likelihood ratio Chi-Square test), $\chi^2(6) = 55.646$, $p < .001$; Goodness-of-fit test (Pearson Chi-Square), $\chi^2(96) = 19.261$, $p = .201$; Pseudo R-squared = 0.513.

Discussion

The increase in sports participation by children and adolescents has created a new population of patients with sport related injuries [7], but the current knowledge about PA related injuries and maturation influence in young children remains limited [38]. Injuries in Portuguese youth were related to PA level, age and also to biological maturation.

PA level

As already addressed in our previous study [8] school and federated sports presented higher prevalence of injury (OR 4.21 and 4.44, respectively). The same pattern was reflected when the sample was divided by sex in the present investigation. The odds ratios in boys, for recreative, school, and federated sports subjects, when compared with no sports participation group, were 1.325, 8.707 and 4.659, respectively; and for girls were 1.742, 3.435 and 3.743, respectively. Data point to the fact that higher injury occurrence is normally related to sport category. Previous research comparing the injury occurrence between elite sports athletes and community-based sports participants, found that this is relatively low for community based sports participants and higher for the federated athletes [13]. Injury prevalence is also substantially lower in sedentary subjects, who only participate on the physical education classes [40]. Highly specialized athletes had 2.25 greater odds of having sustained a serious overuse injury than an unspecialized young athlete [30]. Scholar age subjects who participate in more competitive levels or higher volumes of training have an increased incidence of injury [18,30]. Specifically, exceeding 16 hours per week of total sports participation, regardless of the number of sports, seems to carry the greatest risk [30,31]. These subjects are normally active subjects who play multiple sports, often at an intense level [39]. However, recent studies also are reporting that the risk is even higher when specialized training limits the amount of recreational and unstructured exercise. Young athletes may be able to participate in similar volumes of PA without additional injury risk, meaning the distribution of PA is important [31]. Unlike structured sports practice, unstructured free play is kid directed rather than adult directed, thus probably explaining its lower injury risk. During free play, when a child gets cold, tired, hungry, bored, or sore, she or he will typically stop; but when is being supervised by an adult or is participating in an organized competition, the child may feel an expectation to continue and therefore be more likely to push through pain or soreness. Structured sports training and competition do not always allow adequate rest periods for a developing child [18]. An accurate assessment of each child´s individual sports readiness should be performed to decide if a child is prepared to enroll a certain activity and at which level of competition the child can successfully participate [27]. Despite the problems that arise with active children and adolescents, inactive and less active groups can be at risk on those occasions when they do practice sport [20,35]. This situation was revealed when injury rates were analyzed. Conflicting results presented for the variable occurrence of injury. Injury rate was higher in no sports participation group than in recreative ($p < 001$), school ($p = .046$ and $p < .001$) and federated ($p < .001$) groups, for both sexes. This pattern was already seen in elite athletes with lower injury rates than the general sporting populations [20,35]. Poor physical conditioning is considered by the American Physical Therapy Association as the primary cause of sports injury and there is evidence that physical fitness and experience may play a role in reducing the risk of injury [4]. Low levels of habitual PA and children who have not developed at least some level of strength, endurance and motor skills may be at increased injury risk during leisure-time PA, physical education classes, and sports [9,31]. The lack of diversified activity may not allow the development of the appropriate neuromuscular skills that are effective in preventing an injury. The positive transfer of skills with diversification is important in the successful development of a young child [30].

Age

It is generally acepted that injury ocurrence increases with age [38]. Portuguese data showed also this pattern. Older adolescents had 2.26 more chances to have an injury than the younger ones [8]. In the USA, young athletes who were injured had 1.67 times the odds of being older than 14 years when compared with uninjured athletes, after adjusting for weekly sports hours. The observed increase in injury incidence coincides not only with an increase in age but also with an increase in exposure [5]. For most sports, as athletes get older and advance to higher levels of competition, training volume naturally increases [18]. It is also known that sports attrition rates are the highest during the transitional years of adolescence [27], due to the growth process and development. Also specialization, pressure to perform and intensity, increases with age [20,24,25]. In young athletes, substantial increments in training occur during pubertal years that correspond to the period of maximal annual gains in stature and body mass. This means that the demands of the sport are superimposed on those of normal growth and maturation. High training load overlapping maximal annual changes in growth increases the risk of sport injuries [37]. The present study found age as predictor of injury in the male sample. Boys who had 12-13, 14-15, and >= 16 years were respectively, 2.467, 2.149, and 3.296 times more likely to have an injury than boys who had 10-11 years. Sports involvement lasts later in boys than in girls and their growth process occur later, what can explain why we only found this trend on the male sample.

Maturation

Growth and maturation are potential risk factors for sport injury [37]. Children of the same chronological age may vary considerably in biological maturity status, and individual differences in maturity status influence measures of growth and performance during childhood and adolescence [20]. Studies already confirmed that about one third of all players of one age category were not within their normal maturity category. Chronologic age is not always a good measure for categorizing children and adolescents in competitive levels, and probably not a good development indicator [10]. Athletes more advanced in their biological maturity perform better, were structurally and functionally stronger than their late maturing peers and have a better chance on succeeding in their sport [37]. Unbalanced competition, between early and late maturing in contact sports, contribute to at least some of the serious injuries in these sports [20]. Heavier, faster players generate a larger impact force and the injury risk increases for the opponents and themselves [33]. Cognitive skills, coordination, balance, visual perception, eye-hand coordination are achieved through physical maturation and playing experience. On the other hand, the susceptibility for a variety of musculoskeletal injuries increases during periods of rapid growth because there is an enhanced environment for injury, making the immature musculoskeletal system less able to cope with trauma situations and repetitive biomechanical stress [28]. Longitudinal growth occurs initially in the long bones creating asynchronous development of bone and soft tissue [7]. The soft tissues do not follow this rapid bone growth becoming progressively tighter [27,28] and although controversial, loss of flexibility may occur [20,28]. Muscle-tendon units become tensioned, increasing the risk of joint-related injury [7,18,20,27,28]. Bone mineralization may also lag behind, thus rendering the bone temporarily more porous and subject to fractures [20]. Moreover, biomechanical and clinical evidence suggests that cartilage and growth plates are less resistant than mature adult counterpart [9,28]. Imbalance between strength and flexibility can happen, resulting in structural laxity that is normally present. These results clearly demonstrate biological maturation as a predictor of injury in girls. Mature girls, early mature girls and girls close by PHV showed significant results. Older girls, ahead at least 2.5 years of their PHV seen their risk of injury increased in 2.123 times. As already noted, the effect of age may be partly explanatory however, mature girls have a number of social and morphological conditions that attach them to other tasks in society, which often means having less productive opportunities for PA practice. Their bodies are less adapted (more fat), which often determines restraints in the sport practice itself and a less appropriate response to stimuli. Similarly, early mature girls ($p = .007$) with higher bone age ($p = .012$) also had higher injury risk rates. This pattern was found in some studies where injury incidence was higher in early maturing as compared to late-maturing athletes [12]. In addition, skeletally mature but still muscularly weak subjects were more susceptible to injury compared to peers of the same chronological age. Early maturing players even showed a higher number of tendinopathies and reinjuries [3]. This girls group still faces other circumstance, that is, their cognitive stage may not follow their physical maturation. Young children who are distracted easily may not be capable of participating in highly structured programs. Training programs that do not take into account the child's developmental status may increase the risk for injury associated with the lack of understanding and motivation [9]. Also, girls PHV ($p = .033$) registered higher injury rates. During and after PHV period, increased vulnerability for traumatic and overuse injuries was already reported [37]. Higher injury rates are associated with periods of rapid growth based on developmental stages in young elite female gymnasts [18]. These girls are also more frequently and intensively engaged in sports practice, undergoing an unbalanced phase of motor control and tissue changes. Although the characteristics of this study do not allow us to draw these conclusions, these same girls are exposed to direct contact with mature girls of the same age which causes them a marked disadvantage in terms of size and body proportions. Some studies of female athletes [5,18] had highlighted how maturation can lead to an increased risk of injury although there's still currently a lack of evidence supporting this cause/effect relationship [5]. Risk associated with maturational level still needs to be clarified.

Recommendations

- Due to the variation in timing of maturation, chronological age may not be necessarily an accurate indicator of the level of injury risk. Instead, measures of maturation may offer a more accurate guide, and therefore provide guidance when determining desirable training loads during certain growth and maturation phases (B).
- PA practice contexts should respect physical and psychological immaturity/maturity of the growing athlete (C).

Conclusions

Levels of activity and maturation can be a determinant predictor of injury. Sports injuries arise at all levels of PA and early mature girls, that had just surpassed PHV, may be particularly vulnerable. Assessment of each child´s biological age and individual sports readiness should be performed to evaluate and determine possible risks and to decide at which level of PA the child can successfully participate. Preventing injuries and ensuring safe athletic practices is crucial to achieve the benefits from PA.

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CHAPTER 6

INJURIES CHARACTERISTICS IN CHILDREN AND ADOLESCENTS ACCORDING TO THEIR AGE, MATURATION AND LEVEL OF SPORTS PARTICIPATION

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In Press, Sports Health

Injuries Characteristics in Children and Adolescents According to Their Age, Maturation and Level of Sports Participation

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Abstract

Background: Growth can make young athletes more vulnerable to sports injuries. Few studies have produced information about injury profile and its predictors.

Hypothesis: Are age, maturation and physical activity (PA) level significant predictors of injury type and body area injury location in Portuguese youth.

Study Design: Descriptive epidemiological study.

Level of Evidence: 3

Methods: Injury profile and PA) level information's were obtained by LESADO and RAPIL II questionnaires. They were distributed to 651 participants aged between 10 and 17 years attending four schools. Maturity measures were evaluated through maturity offset (MO) and Tanner-Whitehouse III method. Univariate analysis was used to identify the set of candidate predictors for multinomial logistic regression analysis that was used to determine significant predictors of injury type and body area injury location.

Results: Regarding injury type predictors recreative boys had more chances of having a sprain or a fracture than a strain. Also, recreative and scholar girls had more chances of having a sprain than a strain. As MO decreased, the chances of girls having a strain or a fracture when compared to sprains were higher. For body area location boys with 10-11 years were more likely to have upper limbs injuries than boys of other ages. This was also confirmed by MO. Spine and trunk injuries were more likely to occur in federate and no sports participation girls.

Conclusions: Injury type and body area injury location differed significantly by PA level, age group and MO.

Clinical Relevance: Some injury risk factors are unique to the growing athlete. It's important to recognize PA level and biological age as significant variables when studying injuries in youth. Identifying these associations allows health professionals to detect individuals who may be at risk.

Key words: Injury type, Body area injury location, Children and adolescents, Maturation, Physical activity level

Introduction

Musculoskeletal injuries are the most common injuries in youth sports [37]. Engaging in sports activities at a young age has numerous health benefits but also involves risk of injury. Growth and motor development may yield young athletes more vulnerable to sports injuries [11]. Growth spurt, limited thermoregulatory capacity, maturity-associated variation and lack of complex motors skills needed for certain sports are among the risk factors that may play an important role in the growing athlete [3,28]. An epidemic of both acute and overuse injuries, has been considered, as children make the transition for adolescence, from a variety of free play movements to the specialised pattern of movements imposed by sports [20]. Enhanced environment for injury can occur and several authors reported structural and tissue changes that may contribute to this situation [5,6,20,28,31,32,37]. Asynchronous development of bone and soft tissue take place due to the rapid expansion of bones while growing [11]. The soft tissues do not follow this rapid bone growth and elongate slowly and passively, thus becoming progressively tighter [20,31,32]. Although controversial for some authors, loss of flexibility may occur [28,32] and tension develops across growth plates, apophyses, muscle-tendon units and joints. This increase in tensile forces can place these structures at risk of injury [24,31]. Also an imbalance between strenght and flexibility can happen, and structural laxity it's normally present in children. The period in which trunk length and leg length have already increased, but muscles still have not reached their full size, lack of strength can become a potential cause of injury. This may lead to abnormal movement mechanics and to a motor performance decline during peak height velocity (PHV) [46]. Moreover children's bones are weaker [31], because bone mineralization may lag behind linear growth, thus rendering the bone temporarily more porous [32]. Therefore, there is an increased risk for fractures throughout the bone and growth plate [6,14,31] confirmed through the association between PHV and peak fracture rate [7,14,28]. Likewise, biomechanical and clinical evidence suggests that growth cartilage is less resistant to repetitive microinjury [6,11,14,20,32]. During PHV, growth plate is less resilient to traction and compression forces because is predominantly composed by metabolically active chondrocytes, rather than by extracellular matrix [24]. Also, during adolescence, a decrease in coordination and balance may occur, which not only increases the risk of injury, but also influences sports performance [31].

Sports should as well be suitable for child's cognitive maturation stage. Young children with limited attention, who are distracted easily may not yet be capable of participating in highly structured programs. Child's developmental status may play a role in the risk for injury associated with the lack of understanding and motivation [14]. All these events acting singly or together make the immature musculoskeletal system less able to cope with trauma situations and repetitive biomechanical stress [20,32].

Another factor that also has to be issued is maturity-associated variation. It's consensual that maturity status influence measures of growth and performance during childhood and adolescence. Children of the same chronological age may vary considerably in biological maturity status which can make individual differences appear, creating imbalances in age groups sports participation [8,28]. Some studies already pointed to the fact that about 1/3 of all players of one age category are not within their normal maturity category [17]. There are structural, functional and performance advantages for early-maturity subjects [28,46]. Unbalanced competition between early and late maturers in contact sports contribute to some of the serious injuries in sports [28].

As seen previous studyies [3,12], the most commonly injured areas are lower and upper limbs, being the lower extremity more prevalent [39]. Lower limbs injuries are often a result of strenght and flexibility deficits in the growing athlete [47], and reflects the greater exposure and involvement of the lower chain in physical activity (PA) [12]. Recent studies also have been confirming that injury area distibution differs significantly by age, with children more likely to be seen for boony upper extremity injuries and adolescents more likely to be seen for overuse lower extremity and spine injuries [47].

When the nature/type of injury is the concern, differences also appear. Soft tissues injuries are normally sustained by older subjects when compared with younger subjects. Older children sustain a greater proportion of overuse injuries classified as soft tissue in nature [42,47]. On the other hand, the most common diagnosis in the 5-12 years age group are fractures [6,47]. These studies also indicate sex as a differentiator, with girls more likely to suffer from soft tissue injuries and boys more likely to suffer fractures [42,47]. In previous studies the injuries reported resulted mainly from sprains, strains and fractures [12,36].

As children and adolescents participate in sports in record numbers, targeting risk groups is important [28]. Also, increased knowledge about injury profile and its predictors, associated with specific PA exposures is an important part of an overall risk management strategy [1]. So our aim was to determine injury type and body area injury location predictors in Portuguese youth, engaged in four different levels of sports participation.

Materials and Methods

Ethics Committee of the Faculty of Human Kinetics approved the research protocol. The recommended principles set by the Helsinki Declaration for scientific research involving human beings were also followed, and before inclusion in the study all subjects' guardians gave their written informed consent.

LESADO and Rapil II questionnaires were distributed to 651 participants in four schools, aged between 10 and 18 years involved in different levels of sports participation. LESADO is a self reported questionnaire that gathers information about injury profile. Comes from an extensive literature review on the topic and was adapted and based on epidemiological questionnaires used in Portuguese sports samples[4,12,13,21,38]. As our subjects were children and adolescents, the time to fill out the questionnaires was supervised by the investigator who followed and clarified all doubts, preventing the possibility of bias and interpretation difficulties associated with literacy skills [36,44]. It was also provided a clear definition of injury, based in current epidemiological research [10,48] and time frame used was six months (September 2011 to March 2012), as recommended in retrospective studies [19,41]. The Biosocial Questionnaire RAPIL II is a parent´s self-reported instrument and it was used to measure biosocial variables. It´s been used in Portugal in large epidemiological studies [18,30,50], and provides information about the daily PA habits of the subject. These data allowed to create four groups of PA levels. The no sports participation group, with no time spent in PA per week (except mandatory physical education classes), the recreative sports group with at least 90 minutes of PA per week being at least 60% of this volume of recreational activity; the school sports group with at least 90 minutes of PA per week being at least 60% of this volume of school sports activity and the federated sports group with at least 120 minutes of federated activity.

Maturity measures consisted in calculating bone age and maturity offset. Bone age was obtained according to the Tanner-Whitehouse III (TW3) method [49]. Radiographs of left hand and wrist of thirteen bones were taken in a single session, and the maturity ratings were performed by one trained examiner, without knowledge of the chronological age of the subjects.

Maturity offset assessed time before or after PHV according to Mirwald [33]. Maturity offset minus chronological age provides an estimate of the age of PHV. It can be used to group the individuals for years before or after PHV. We used a specific equation for each sex (SEE equation is 0.592 for boys and 0.569 for girls), based on the Canadian and Belgian samples [33]. Applicability of the method appears to be useful during the period of growth acceleration, between 12-15 years [29]. Chronological age group was defined with the whole year as the midpoint of the range (e.g.,12 years include participants with 11.50 to 12.49 years of decimal age).

The statistical analysis was conducted using SPSS 22.0 software (SPSS Inc., Chicago, IL, USA) and a significance level of 5% was considered. The dependent variables were injury type (0 = strain, 1 = sprain 2 = fracture) and body area injury location (0 = lower limbs, 1 = upper limbs, 2 = spine and trunk). Despite some issues that prevent the use of multinomial regression models in case of body area injury location, this technique was initially considered to identify the significant predictors for each sex and for each dependent variable. The evaluated predictors were PA level (0 = no sports participation, 1 = recreative, 2 = scholar, 3 = federate), age group (0 = 10-11, 1 = 12-13, 2 = 14-15, 3 = ≥ 16 years), bone age (years) and maturity offset (years). First, univariate analyses of predictors were conducted: Chi-square tests of independence and Kruskal-Wallis tests were used for categorical and quantitative predictors, respectively. The set of candidate predictors for multinomial regression consisted of all the variables that presented $p < .25$ in the univariate analysis [23], and the backward stepwise method using the likelihood ratio statistic was applied for the model variable selection.

Results

A total of 651 adolescents participated in this study, aged between 10 and 18 years (M = 13.7; SD = 1.8 years), being 343 boys (52.7%) and 308 girls (47.3%).

Boys – Predictors of Injury Type

Significant associations were found only between injury type and PA level (X2(4) = 12.763, p = .011). Recreative boys were more likely to have a fracture and less likely to have a strain than the other two PA levels studied (the school sports group was withdrawn due to the reduced number of observations). Backward stepwise methods lead to a multinomial logistic regression model with only this predictor, as expected (X2(4) = 15.165, p = .004). The odds of a recreative boy having a sprain rather than strain were 8.84 times more than for a federate boy and the odds of a recreative boy having a fracture rather than a strain were 7.27 times more than for a federate boy. Results can be seen in Table 1.

Girls – Predictors of Injury Type

Regarding girls, Kruskal-Wallis tests showed that there were significant differences in bone age (X2(2) = 9.616, p = .008) and maturity offset (X2(2) = 12.892, p = .002) among injury type. Post hoc tests revealed that in bone age (p = .007) and in maturity offset (p = .002) the significant differences were between fracture and sprains. Although PA level was not a significant predictor in the univariate analysis, it was considered for the multinomial logistic regression since together with other predictors could be significant. The multinomial logistic regression model achieved two predictors, PA level (X2(6) = 16.474, p = .011) and maturity offset (X2(2) = 15.115, p = .001). The odds of a recreative girl having a sprain rather than a strain were 7.46 times more than a federate girl and the odds of a scholar girl having a sprain rather than a strain were 20.8 times more than a federate girl. Relatively to maturity offset, the odds ratio revealed that as maturity offset decreased by a unit, the change in the odds of having a strain rather than a sprain were 1.71; and of having a fracture rather than a sprain were 2.32. Results are presented in table 1 and figure 1.

Table 1 - Multinomial logistic regression models adjusted for the dependent variable injury type for each sex.

Dependent variable	Predictor	*B* (Std Error)	*p*	odds ratio	95% CI odds ratio
Type of injury[1]		Boys[3]			
Sprain	Intercept	−0.793 (0.276)	.004		
	PA level (1)	0.100 (0.672)	.882	1.105	(0.296, 4.125)
	PA level (3)	2.180 (0.838)	.009	8.842	(1.713, 45.651)
Fracture	Intercept	−0.480 (0.250)	.055		
	PA level (1)	−1.600 (1.090)	.142	0.202	(0.024, 1.709)
	PA level (3)	1.984 (0.821)	.016	7.269	(1.455, 36.306)
Type of injury[2]		Girls[4]			
Strain	Intercept	2.272 (0.810)	.005		
	Maturity offset	−0.538 (0.224)	.016	0.584	(0.376, 0.906)
	PA level(1)	−1.249 (0.756)	.098	0.287	(0.065, 1.262)
	PA level(2)	−2.012 (0.824)	.015	0.134	(0.027, 0.673)
	PA level(3)	−3.029 (1.239)	.015	0.048	(0.004, 0.549)
Fracture	Intercept	2.050 (0.895)	.022		
	Maturity offset	−0.842 (0.253)	.001	0.431	(0.262, 0.707)
	PA level(1)	−1.869 (0.974)	.055	0.154	(0.023, 1.041)
	PA level(2)	−1.541 (0.932)	.098	0.214	(0.034, 1.330)
	PA level(3)	−0.572 (0.945)	.545	0.564	(0.089, 3.596)

[1] The reference category is strain.
[2] The reference category is sprain.
[3] Model $X^2(4) = 15.165$, $p = .004$; Cox & Snell $R^2 = .120$; Nagelkerke $R^2 = .135$; McFadden $R^2 = .059$.
[4] Model $X^2(8) = 28.770$, $p < .001$; Cox & Snell $R^2 = .290$; Nagelkerke $R^2 = .328$; McFadden $R^2 = .158$.

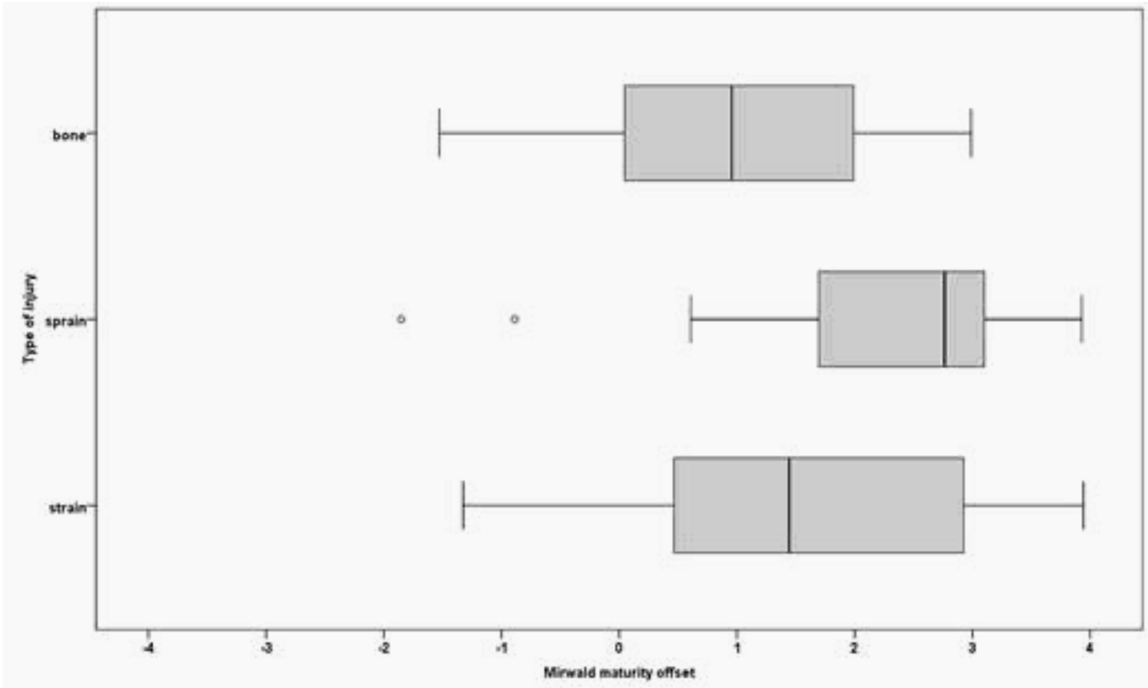

Figure 1 - Boxplots of maturity offset for girls by type of injury

Boys – Predictors of Body Area Injury Location

A significant association was found between body area injury location and age group (X2(6) = 13.587, p = .033). Boys with 10-11 years were more likely to have upper limbs injuries than boys of the other age groups and less likely to have lower limbs injuries than boys of age groups 14-15 and ≥ 16. Kruskal-Wallis tests also revealed that significant differences emerged in maturity offset (X2(2) = 6.014, p = .049). Post hoc tests showed that the differences in maturity offset were between upper limbs and lower limbs (p = .045). See figure 2.

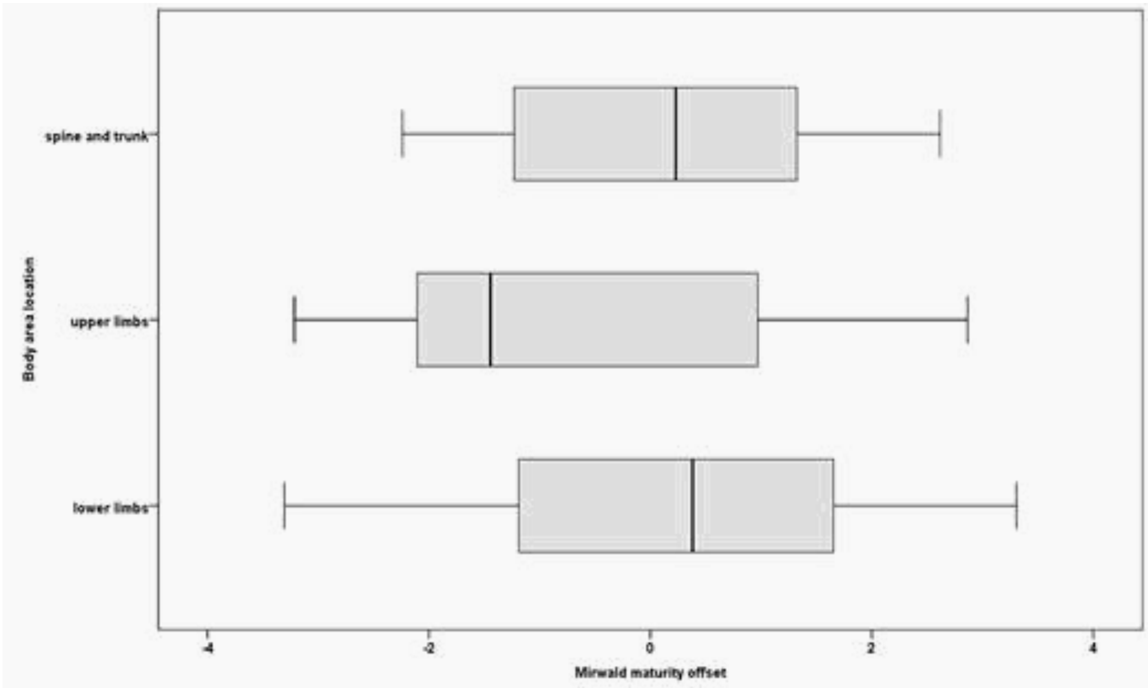

Figure 2 - Boxplots of maturity offset for boys by body area injury location

Girls – Predictors of Body Area Injury Location

A significant association was detected between body area injury location and PA level ($X2(6) = 14.587$, $p = .022$). Federate girls were more likely to have spine and trunk injuries than scholar and recreative girls, and girls with no sport participation were more likely to have spine and trunk injuries than recreative girls. See figure 3.

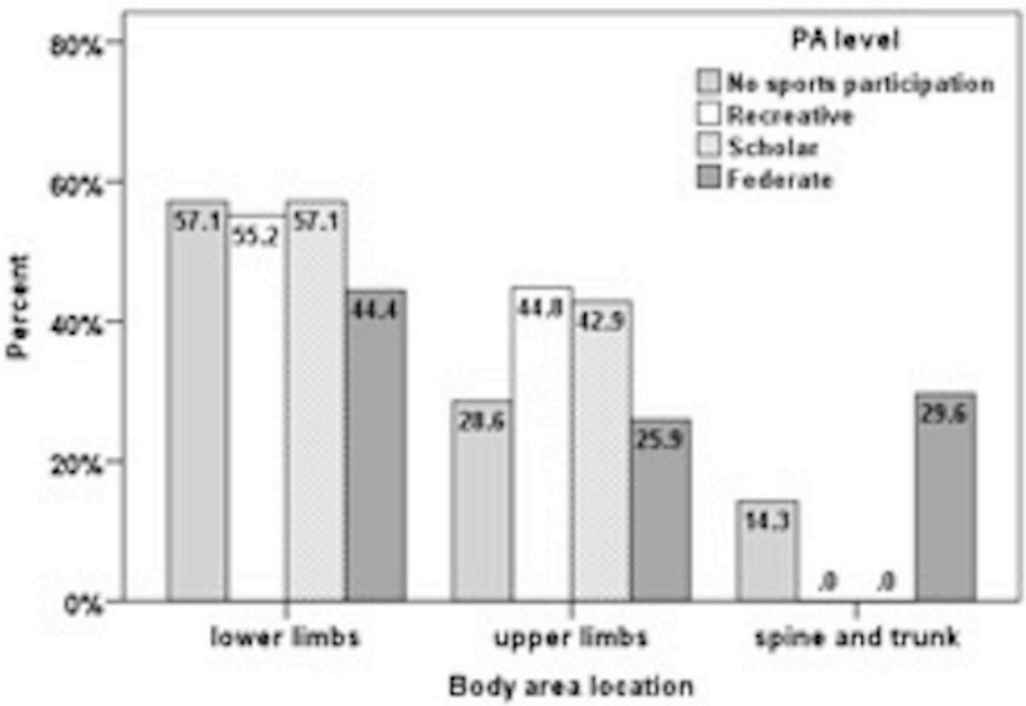

Figure 3 - Percentage of injuries of girls by body area injury location for each PA level

The reduced number of spine and trunk injuries for both boys and girls prevented the use of multinomial logistic regression in case of body area injury location.

Discussion

Injuries in school age children from different PA backgrounds have a specific identity, being age, PA level and maturation very important predictors of body area injury location and injury types. With respect to PA level we have found different results for each sports group. Girls in the no sports participation group presented more chances of having a spine or trunk injury. Scholar girls were more likely to have sprains than strains. Boys and girls of the recreative group were more likely to have sprains, and boys also fractures, than strains. Federated girls and boys reported more strains, rather than sprains or fractures. These federated girls were also more likely to have spine and trunk injuries. As maturity offset is concern, strains and fractures were more likely to occur in girls near the PHV. In boys upper limbs injuries were more likely to occur before PHV, and lower limbs injuries after PHV. Group age results were very similar to maturation results.

Boys with 10-11 years were more likely to have upper limbs injuries than boys of the other age groups and less likely to have lower limbs injuries than boys of age groups 14-15 and ≥ 16.

PA level

Injuries are normally related with the specificities of the practiced activity [12,13,39]. The distribution through the different levels of sports participation seems to be one of the key variables in regard to injury type. Scholar girls were more likely to have sprains rather than strains 20.8 times. Like it was proven by several studies, sprains are one of the most common injuries sustained by young athletes [3,39] and highly related with traumatic mechanisms [40], due to joint stiffness and abnormal movement mechanics during growth [46]. The traumatic nature of injuries found in our data can be a factor that contributes to this pattern, and sex differences can be explained by the higher involvement of girls in scholar sports [12]. In addition, concerns about school sports have been raised due to the poor quality of the playing fields, inappropriate protective equipment and inefficient supervision [5]. Improper environments and incorrect equipment can also contribute to these types of injury [43]. Boys and girls of the recreative group were 8.84 and 7.46 times respectively more likely to have sprains than strains, and boys had 7.27 times more chances of having a fracture rather than strains. Sprains are a very much popular injury in this age group with no relevant distinction between boys and girls. The concerns raised in regard to scholar sports about environmental, equipment and supervision issues are also present in recreative sports. Also recreative sports can be practiced in a variety of settings, which can add complexity to injury patterns. As fractures in boys are concerned, younger males tend to sustain during sports practice, more accidental injuries, especially fractures, than girls, older children and adults [35]. Recent studies reported that fractures represented 10% to 25% of all injuries sustained by high school athletes and were more common among males [7,48]. The high incidence of fractures in childhood result from a transient deficit in bone mass related to longitudinal growth. The pubertal period of transient fragility has also been suggested to be due to an increased bone porosity [7]. Gender differences in bone injuries could be explained by earlier skeletal maturity among girls [48], fact seen in our sample since most of the girls were already mature. Federated girls and boys reported more strains, rather than sprains or fractures. Federated athletes sustain a greater proportion soft tissue injuries and a large percentage can be classified as overuse. Recent studies are beginning to emphasize and describe overuse injuries as the most significant mechanism of injury in organized sports. The increasingly highly competitive nature of youth sports, increased periods of extensive training, repetitive movements, sport specialization and participation in large numbers of competitive events [12,15,42] have made overuse injuries a growing reality. Subjects who have not developed some skills like strength, endurance, and motor control may be at increased injury risk as they begin or get more involved in a specific sport [14]. Changes in length, mass and body composition are also mentioned as potential causes. These changes put increased stress on the bone-muscle-tendon junctions, ligaments and growth cartilage. Those tissues are not immediately able to deal with the increased stress, resulting in a temporary imbalance in the capacity to deal with this load. Especially in elite youth athletes, where this imbalance is combined with intensive training this may increase susceptibility to overuse injuries [46]. Also in organized competition, the child may feel an expectation to continue and therefore be more likely to push through pain or soreness. Structured sports training and competition do not always allow adequate rest periods for a developing child [24].

Girls in the no sports participation and federated groups presented more chances of having a spine or trunk injury ($X2(6) = 14.587$, $p = .022$). It has already been found associations between low back pain (the most prevalent spine and trunk injury) and the number of hours spent watching television and the number of hours spent practicing competitive sports [25]. Low levels of PA and sedentary lifestyle can be considered a risk factor. Physical inactivity can result in decreased strength, bone mineral content, flexibility and coordination, and these factors can contribute to the appearance of symptoms, especially in girls [2,45]. Sedentary lifestyle is also related to increased body fat mass. Several researchers have claimed that female samples with higher levels of localized abdominal fat are more prone to suffer from spine disorders [22,26]. On the other hand, as already addressed, it is also common scientific studies to report young athletes as a risk group for spine dysfunction [9,16]. Low back pain in athletes is usually directly related to sports practice. Symptoms or degenerative changes in the spine can occur. The protective effect of sports participation disappears, manifesting a harmful effect with high training volumes and intensities. Functional or repetitive overload and/or charges introduced early, not adapted to the growth and physiological characteristics of the athlete are usually the main causes [27,34].

Maturity Offset

As maturity offset is concern, strains and fractures were more likely to occur in girls near the PHV. The odds ratio revealed that as maturity offset decreased by a unit, the change in the odds of having a strain rather than a sprain were 1.71; and of having a fracture rather than a sprain were 2.32. It´s consensual that around the PHV period, adolescents are vulnerable to injuries [8,13,43]. Physiological loading is beneficial for the bones, but excessive load may produce serious injuries, like strains [43].

An increase in traumatic injuries takes place mainly during the year of PHV, while the increase in overuse injuries persists in the year after PHV. The factors that are reported as responsibles for an increase in traumatic injuries like joint stifness, decreased bone density, abnormal movement mechanics disappeared in the year after PHV, in contrast to factors contributing to overuse injuries. A period in which trunk length and leg length have already increased, but muscles still have to reach their full size and strength creates an imbalance between strength and flexibility. This may lead to abnormal movement mechanics and a decline in performance on motor tasks during the interval of PHV. Possibly, this temporarily decline in essential motor performance during years of maximal growth contributes to an increase in traumatic injuries [46]. Additionally a decrease in bone mineral density occurs before the attainment of PHV and correlates with acute fracture episodes [7,14,24,46]. In healthy girls, fractures during childhood and adolescence are more frequent with later than earlier menarche. This higher fracture incidence in late maturers is associated with significant deficits in bone mass, microstructure and strength estimates [7]. As overuse injuries are concerned, authors have explained its causes from a biomechanical perspective. First, changes in bones limb mass typically occur before changes in muscle tissue. If muscles, tendons and apophyses adapt slowly, and activities are performed repetitively, those tissues are not immediately able to deal with the increased stress and overuse injuries may occur, leaving a period of increased susceptibility after PHV [46]. Moreover, it should be noted that girls presented higher overuse injury rates than boys, and greater proportion of their overuse injuries occurred earlier [42]. Girls mature earlier than boys and there is a greater and longer gain in bone size in males than in females during pubertal maturation [7], which may later predispose boys for these injuries. Relatively to body area injury location, only boys presented significant results. Boys' upper limbs injuries were more likely to occur before PHV, and lower limbs injuries after PHV ($p = .045$). These results reflect the type of injury associated to growth velocity during adolescence, and its relation to body area injury location, where traumatic upper limb bony injuries can occur more often in children/adolescents before PHV, and soft tissue lower limb injuries in adolescents after PHV. It is known that significantly larger proportion of injuries sustained by older children are to soft tissues when compared with younger athletes. Younger athletes are more likely to have bone fractures and are treated for a greater proportion of traumatic injuries [6]. These fractures are normally located in the upper limbs [48]. During puberty, the asynchrony between the acceleration of standing height and bone mineral content gain is also associated in the distal radius with a transient cortical deficit with an increased porosity that may well contribute to the adolescent increased incidence in forearm fractures [7]. On the other hand increased stress on the muscle-tendon-bone junctions, ligaments, and growth cartilage occurs as the changes in the length, mass, and moment of inertia of the extremities take place with growth. The increases in strength needed to accommodate these changes may not occur in a uniform pattern and may enable the child or teenager to continue to generate the same limb speed as before the growth spurt. These complex factors and combinations of growth, strength, load, sport training and competition, create situations conducive to the development of overuse injuries, especially in lower limbs [14].

<u>Age Group</u>

Group age results reflect the maturation results. Boys with 10-11 years were more likely to have upper limbs injuries than boys of the other age groups and less likely to have lower limbs injuries than boys of age groups 14-15 and ≥ 16 ($X2(6) = 13.587$, $p = .033$). This pattern is highly related to the PHV process, with all the structural and tissue changes already explained. Some authors are starting to recognize that the effect of age on injury risk may be trivial [8,13]. Also during growth, some subjects experience a decrease in coordination and balance, and lack complex motor skills, what may predispose them to falls, contact injuries and possible traumatic upper limb injuries, mechanism quite common at these ages. Although after PHV, tissue and structural dynamic equilibrium begins to be reached some degree of fragility still persists, especially in soft tissues. These factors contribute to lower limbs become more affected at that stage.

Recommendations

- Due to the variation observed in growth and maturation between adolescents, chronological age is an incomplete indicator for injury risk. Inter-individual variability in biological maturation corresponds to variation in readiness for sport and by inference in vulnerability to specific injuries (B).

- Players of any context of PA should ideally be matched for body size, athletic ability and biological maturity. Coaches and professors should consider this as they plan their PA sessions in order to all children/adolescents continue to benefit from sports practice, adjusted to the skills and specificities of each body (C).

Conclusions

It's important to recognize PA level and maturation as significant variables when studying injuries in children and adolescents. Each sport group presented a specific injury profile and PHV proved to be an important milestone for the evaluation of the injury characteristics in children and adolescents of both sexes. It seems warranted that the influence of maturity status and PA level on injury characteristics should be investigated in more detail in future studies [17].

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CHAPTER 7

INFLUENCE OF PHYSICAL ACTIVITY INTENSITY AND MATURATION IN INJURY PROFILE ON CHILDREN AND ADOLESCENTS

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Influence of Physical Activity Intensity and Maturation in Injury Profile on Children and Adolescents

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ABSTRACT

Objectives: Determine injury profile predictors in Portuguese youth.

Design: Epidemiological study.

Participants: 121 participants aged between 10 and 18 years.

Setting: Four portuguese community schools.

Main Outcome Measures: Injury was assessed via a questionnaire (LESADO), Physical Activity (PA) intensity via accelerometry and maturity via Tanner-Whitehouse III bone age and maturity offset. Binary logistic, linear and multinomial logistic regressions analyses were used to determine significant predictors of injury profile.

Results: For body area injury location differences were seen between lower limbs and upper limbs ($\chi^2(6) = 70.820$, $p < .001$). The odds of having a lower limb increased 1.02 times for each minute of time spent in moderate-vigorous PA. In injury type differences distinguished both strains and fractures from sprains. Time spent in moderate PA ($\chi^2(2) = 6.701$, $p = .035$) and bone age ($\chi^{2(}2) = 7.196$, $p = .027$) were the final predictors. The odds of having a strain or a fracture increased 1.04 times for each minute of time spent in moderate PA. Likewise the odds of having a strain or a fracture decreased 1.7 times for year of bone age.

Conclusion: PA intensity and bone age proved to be injury predictors of the growing athlete.

Keywords: Sports Injuries; Accelerometry; Physical Activity Intensity; Bone Age.

Highlights:

- Time spent in higher intensities of PA increases the risk for lower limbs injuries.

- Time spent in moderate PA increases the risk for strains and fractures.
- Subjects with lower biological age presented higher risk for strains and fractures.

INTRODUCTION

Despite the growth in participation of younger generations in sports and physical activity (PA), significant lack of knowledge exist regarding sports injuries in youth subjects [44]. The increased sports involvement from an early age through the years of growth raises serious concerns [32,44]. There´s a general trend toward specialization, intensive training and competition in early to middle childhood. These factors combined with a growing body can predispose the young child to sports injuries that may determine long-term dysfunction [15,44]. Intensity of youth sports not only sacrifice fun but also produce injuries, burnout, social isolation, dropouts and may lead to reduced motor skill development [11,15,32,44]. If the cycle of sports specialization occurs too early in youth motor skills and neuromuscular development will be impaired which in turn increases the risk of injury and potentially reduces opportunities for the child to achieve optimal sport performance [16,32]. Although scientific results support that sports specialization and specific skill development is necessary to achieve elite levels, it has been discussed whether such intense practice time must begin during childhood and to the exclusion of other sports to maximize potential for success [15,19]. For most sports there is still no evidence that highly structured intense training and specialization before puberty are necessary to maximise sports performance. Also there is a concern that these approaches before adolescence may be harmful to a young athlete [15,19,32]. Clear guidelines set by multiple health organizations, designed to reduce injury rates, stated that intensive training of children has no physiological or educational justification and claimed that diversity of movement and all-round physical conditioning should have priority over specialization. They also advised that specialization in a single sport before adolescence should be discouraged. Moreover age appropriate levels of competition should be respected [15,31]. Likewise several studies have come to realize the association between injuries and higher intensity and volume of training, higher competition level, long training sessions that require repetitive movements, overscheduling and overtraining [11,15,24,26,31,32]. Recent studies, pointed out the increase of sports participation, load and/or intensity prior to injury [24,43].

These injuries may also be linked to the unique and vulnerable phase of the musculoskeletal, motor and cognitive development of youth. High training intensities overlapping growth spurt increases the risk of sports injuries [41]. The immature musculoskeletal system passes through several structural and tissue changes and may become less able to cope with trauma situations and repetitive biomechanical stress [20,28]. These changes include asynchronous development of bone and soft tissue [6]. Longitudinal growth leaves the bone temporarily more porous and therefore fragile [20]. Soft tissues do not follow this rapid bone growth and become progressively tighter [28] increasing tensile forces over growth plates, cartilage, apophyses, muscle-tendon units and joints [6,10,15,20,28]. Likewise, muscles don´t reach their full size until 6 to 12 months after peak height velocity (PHV) imposing to youth during this stage a decrease of strenght. Also an imbalance between strenght and flexibility can happen as well as abnormal movement mechanics [41]. Furthermore during adolescence motor control can be affected by changes in balance and coordination which may have an impact on injury risk [28]. Equally cognitive maturation at this stage is an important factor to consider. Children and adolescents with less concentration may not yet be capable of participating in very demanding activities [10].

Despite the heightened awareness about sports injuries the available evidence is still limited and inconclusive, particularly with respect to reliable data about predictors like biological age and PA intensity [4,15]. So our aim was to identify the importance of PA intensity and maturity as predictors of injury ocurrence, injury rate, body area injury location and injury type in Portuguese children and adolescents.

MATERIALS AND METHODS

A total of 121 participants of four portuguese schools, aged between 10 and 18 years, were attended to wear an ActiGraph GT3X activity monitor (Actigraph LLC, Fort Walton Beach, Florida, USA). It was worn around the waist, for five consecutive days (three weekdays and two weekend days). This device is a small accelerometer (3.8 × 3.7 × 1.8 cm), lightweight (27 g), which uses a piezoelectric acceleration sensor to collect motion data on three axes: vertical (Y), horizontal right-left (X) and horizontal front-back (Z). This data is filtered into signals of frequency in a rate of hertz, during an interval of time or epoch [18,48]. The epochs were defined into 1 second of time wear, lately converted into 5 seconds counts of activity, which are linearly related to the intensity of PA during those periods of time [37]. A valid day was defined as a day with more than 600 minutes of device wear, and non-wear periods were determined as more than 60 continuous zeros of activity counts [47]. Participants were only included in the study if they had at least three valid wear days. All participants were instructed to wear the accelerometer while they were awake and to take it off for any water activity (e.g. showering or swimming), if the device compromised the physical performance or its integrity (e.g. gymnastic or sports fight) and activity that involved cycling or rolling. During the aforementioned when the participants took off the accelerometer they were instructed to record in a diary [47]. The information registered in those diaries was coded by the time engaged in those activities multiplied by the MET (Metabolic Equivalent Task) estimated values according the Compendium Energy Expenditure [36]. Those activities were included in the daily PA at the correspondent day, replacing the hourly assumed as unworn, and than added for the valid days [27].

The PA intensity level was classified according to moderate, vigorous or very vigorous intensity PA as proposed by Freedson [13]. The time encompassed in moderate and vigorous PA (MVPA) was determined [13]. Mean time per day at the different intensities levels was determined by summing all minutes spent in the count criteria and divided by the valid days. The defined cut-points proposed by Freedson equation [13] were 500-3999 counts for moderate intensity level, 4000-7599 counts for vigorous intensity level and 7600 or above counts for very vigorous intensity level.

To assess injury profile LESADO questionnaire was used. LESADO is a self reported questionnaire that gathers information about injury profile. Valid and reliable information about injury on children aged 10+ years [12] can be obtained through a self-report survey [40]. Neverthless children under the age of 12 years may require assistance to complete the survey [40]. To prevent bias and interpretation difficulties all subjects were followed by the investigator in completing the questionnaires. Time frame used was 6 months (September 2011 to March 2012) as recommended in retrospective studies [14]. It was also provided a clear definition of injury based in current epidemiological research [17,45]. LESADO comes from an extensive literature review on the topic and was adapted and based on epidemiological questionnaires used in Portuguese sports samples [1,8,9,34].

Maturity measures consisted in determining maturity offset during adolescence (time before or after PHV according to Mirwald [29]) and in calculating bone age through radiographs of the left hand and wrist according to the Tanner-Whitehouse III Method (TW3)[46]. X rays were performed in a single session and thirteen bones ossification were evaluated. Maturity ratings were performed by one trained examiner without knowledge of the chronological age of the subjects. Maturity evaluation was independently replicated two weeks later by the same observer and the intra-observer TME was determined. An expert observer evaluated a random subsample of 37 radiographies and the inter-observer TME was determined. The intra-observer TME was .03 (.04) years and the inter-observer TME was .03 (.99) years.

Maturity offset was predicted from a specific equation for each sex (SEE equation is 0.592 for boys and 0.569 for girls) based on Canadian and Belgian samples [29]. Can be used to classify adolescents as pre or post PHV and is also possible to group the individuals for years before or after PHV. Chronological age minus maturity offset provides an estimate of the age of PHV. Applicability of the method appears to be useful during the period of growth acceleration [23]. Chronological age was defined with the whole year as the midpoint of the range (i.e.,12 = 11.50–12.49).

Before inclusion in the study all subjects' guardians gave their written informed consent. The research protocol was in accordance with the Helsinki Declaration and was approved by the Ethics Committee of the Faculty of Human Kinetics.

The statistical analysis was conducted using SPSS 22.0 software (SPSS Inc., Chicago, IL, USA) and a significance level of 5% was considered. Descriptive statistics was used to determine the sample characteristics. In order to perform descriptive data, age groups, maturity offset categories and bone maturity categories were defined. Age groups had an interval of two years (0 = 9.5–11.49 years, 1 = 11.5–13.49 years, 2 = 13.50–15.49 years, 3 = ≥ 15.50 years). Maturity offset categories were defined as pre PHV, on PHV and pós PHV (0 = < −0.5 years of PHV, 1 = [−0.5, 0.5] years of PHV, 2 = > 0.5 years of PHV). Bone maturity categories were divided in three: late maturers, when the bone age was inferior to the decimal age in over one year; normal maturers, when the difference between the bone and decimal ages was one year at the most; and early maturers, when the bone age was superior to the decimal age in over one year (0 = late, 1 = on time, 2 = early) [21,22]. The variable selection started with a bivariate analysis of the dependent variable and each predictor. The dependent variables were injury occurrence (0 = no and 1 = yes), injury rate (number of sports injuries per 1000h of exposure), injury type (0 = strain, 1 = sprain, 2 = fracture) and injury body area location (0 = lower limbs, 1 = upper limbs). The evaluated predictors were sex, PA intensity (in minutes and categorized by the different levels of intensity proposed by Freedson [13]), decimal and bone age (years) and maturity offset (years). The set of candidate predictors for multiple regressions consisted of all the variables that presented $p < 0.25$ in the bivariate analysis and a backward stepwise method using the likelihood ratio statistic was applied for the model variable selection. Only injury body area location and injury type presented significant results. Binary logistic regression was used in order to identify the significant predictors of injury body area location and multinomial logistic regression was used to identify the significant predictors of injury type.

RESULTS

A total of 121 subjects aged between 10 and 18 years participated in the present study. From this sample 51 participants (42.1%) reported a sports injury during the previous 6 months. Considering the analysis by sex, 22 of 57 boys reported injury (38.6%) and 29 of 64 girls reported injury (45.3%). The mean decimal age of the subjects was 13.8 years (*SD* = 1.9), quite similar to mean bone age (*M* = 13.8; *SD* = 2.2). Maturity offset presented mean values of 0.7 years (*SD* = 1.7) after PHV. Considering the sample that reported a sports injury, the average injury rate was

11.2 (*SD* = 6.2) per 1000h of PA exposure. The most injured body areas were lower limbs (62.0%) followed by upper limbs (24.0%). The type of injuries found were strains (34.1%), sprains (38.6%) and fractures (27.3%). Looking at table 1 we can see time spent on PA (minutes) by levels of intensity considering total sample, sex, age, maturity categorical variables and injury profile variables.

Table 1 - Mean and standard deviation[1] of time spent (minutes) on each PA intensity level by total sample, sex, age, maturity and injury profile.

	PA Intensity (minutes)			
	Moderate	**Vigorous**	**Very Vigorous**	**Total MVPA (moderate to vigorous PA)**
Total Sample	109.59 (35.21)	18.55 (14.79)	5.49 (13.20)	134.57 (52.90)
Sex				
Male	119.12 (39.63)	25.43 (16.93)	8.82 (17.82)	156.07 (62.01)
Female	101.09 (28.45)	12.42 (8.99)	2.52 (5.54)	115.41 (33.48)
Age Group				
9.5-11.5	132.50 (39.27)	17.97 (9.31)	3.74 (3.77)	154.22 (45.97)
11.5-13.5	124.98 (31.55)	19.55 (13.34)	8.71 (22.41)	158.36 (66.78)
13.5-15.5	97.40 (30.86)	16.52 (18.05)	4.59 (9.63)	117.67 (45.57)
>=15.5	95.11 (27.33)	21.76 (13.15)	4.68 (7.76)	121.55 (35.24)
Maturity Offset				
< –0.5	132.34 (40.48)	20.55 (11.97)	8.65 (20.46)	165.81 (67.83)
-0.5 <= PHV <=0.5	121.20 (23.31)	24.70 (22.81)	2.87 (2.67)	148.76 (36.57)
Mirwald > 0.5	94.24 (26.21)	15.83 (12.95)	4.50 (9.20)	113.97 (35.84)
Bone Maturity				
Late	121.35 (39.41)	22.20 (18.27)	6.11 (12.48)	149.67 (49.09)
On time	105.98 (31.60)	17.64 (14.06)	4.79 (13.31)	130.33 (54.85)
Early	110.60 (43.02)	17.91 (13.10)	7.81 (14.04)	134.10 (47.53)
Injury Ocurrence				
No	110.47 (38.63)	17.97 (13.97)	4.47 (13.53)	135.1 (6.67)
Yes	108.37 (30.23)	19.35 (15.95)	6.9 (12.75)	133.84 (38.3)
Injury Rate	108.37 (30.23)	19.35 (15.95)	6.9 (12.75)	133.84 (38.3)
Body area injury location				
Lower limbs	110.98 (31.52)	21.75 (18.25)	7.28 (13.71)	140.01 (37.95)
Upper limbs	98.46 (22.51)	13.81 (9.73)	5.06 (11.18)	114.0 (31.12)
Injury Type				
Strains	118.02 (29.91)	25.11 (21.55)	5.22 (9.24)	148.36 (40.24)
Sprains	88.98 18.21)	19.47 (15.1)	12.3 (19.18)	118.38 (34.04)
Fractures	117.38 (32.92)	15.30 (8.82)	4.25 (4.44)	136.93 (37.91)

[1] The results are presented in the following format: mean (standard deviation).

Injury Occurrence and Injury Rate – Predictors

There weren´t found significant results for both variables.

Injury Body Area Location - Predictors

Total time spent in MVPA intensity was selected for the final model ($\chi 2(6) = 70.820$, $p < .001$). The odds of having a lower limb injury compared to an upper limb injury increased 1.02 times for unit increment (minute) of total time spent in MVPA. The variable time spent in vigorous PA, that was a significant predictor in the preliminary analysis, lost significance in the binary logistic regression model. The results are shown in Table 2.

Table 2 - Binary logistic regression model (1 = lower limbs, 0 = upper limbs) for injury body area location[1].

Predictor	B(SE)	*p*	odds ratio	95% CI odds ratio
Constant	−1.769(1.371)	.197	0.17	
Total time spent in moderate and vigorous PA	0.022(0.011)	.050	1.02	(1.00, 1.04)

[1] Cox & Snell R^2 = .100; Nagelkerke R^2 = .144; Percentage of correct classification = 67.4%.

Injury Type - Predictors

The significant multinomial logistic regression equation ($\chi^2(4) = 19.377$, $p = .001$) that was considered included time spent in moderate PA intensity ($\chi^2(2) = 6.701$, $p = .035$) and bone age ($\chi^2(2) = 7.196$, $p = .027$) as predictors. These variables were significant in distinguishing both strains and fractures from sprains. The odds of having a strain or a fracture compared to having a sprain increased 1.04 times for unit increment (minute) of time spent in moderate PA. Likewise, the odds of having a strain or a fracture compared to having a sprain decreased 1.7 times for unit increment (year) of bone age. The variable time spent in MVPA, decimal age and maturity offset, that were significant predictors in the preliminary analysis, lost significance in the final multinomial logistic regression model. The results can be seen in Table 3.

Table 3 - Multinomial logistic regression model for injury type [1]

Injury type[2]	Predictor	B(SE)	*p*	odds ratio	95% CI odds ratio
strain	Constant	3.794 (4.180)	.364		
	Time spent in moderate PA	0.040 (0.019)	.035	1.04	(1.00, 1.08)
	Bone age	−0.549 (0.246)	.025	0.58	(0.36, 0.94)
fracture	Constant	3.744 (4.313)	.385		
	Time spent in moderate PA	0.039 (0.019)	.044	1.04	(1.00, 1.08)
	Bone age	−0.555 (0.254)	.029	0.57	(0.35, 0.94)

[1] Cox & Snell R^2 = .356; Nagelkerke R^2 = .402; McFadden R^2 = .202.
[2] The reference category is sprain.

DISCUSSION

Nowadays youth sports participation has evolved from children recreational free play to adult driven. It has become an extremely structured activity practiced at high intensity levels and devoted to sports specific skill development. Sports injuries usually result from the combination of several risk factors interacting at a given time [35]. Biological development in adolescence and PA intensity levels can be a part of this complex equation. The purpose of this investigation was then to identify the influence of PA intensity and maturity as predictors of injury profile in Portuguese children and adolescents. So far there aren´t studies that accurately quantify maturation and PA intensity levels which makes this study new in its approach. The obtained results showed that injuries in the maturing athlete, who practice sports at moderate and vigorous levels of PA intensity, have a specific identity. Lower limbs injuries risk increased with higher total time spent MVPA and the risk of a bone or muscle-tendon injury increased with higher time spent in moderate PA and in lower bone ages.

Biological and Injury Profile Characteristics

Descriptive data of injury prevalence, injury rate and injury profile were quite similar to the results of previous studies [8,9]. Injury prevalence and injury rate in Portuguese school age children presented significant results. Lower and upper limbs were the most affected areas and strains, sprains and fractures were the major injuries registered. This sample didn’t present significant differences between decimal age and bone age. Nonetheless maturity offset mean and standart deviation showed that study participants were in their majority near or in PHV stage.

Recorded PA intensities for both sexes were mainly moderate. Daily time spent in vigorous and very vigorous PA intensity levels were low. Portuguese children and adolescents do not reach sufficient PA as recommended by international health recommendations [30,33]. Vigorous PA intensity level account for the lowest proportion of overall PA among young people and may decline more rapidly than any other PA intensity during this period [7]. Age groups results also showed that as the age increases the minutes spent on MVPA decreases. Although it’s widely accepted that PA intensity rise with subject’s age studies have consistently shown that PA declines throughout adolescence [2,5], especially vigorous PA [7]. Time available to PA practice is reduced in this transition from childhood to adolescence. Despite the steadily increase of organized sport participation during the last few years the evidence showed that active play during leisure as well as non organized sport activities seems to be reducing due to increasing access to technology and other activities [30]. Also other responsibilities can arise such as part-time jobs or more hours devoted to studies [5]. Moreover influences of school environment and peer groups can strongly exert effect on PA behaviours [5,25].

Maturity offset and bone maturity category groups results presented a similar pattern. Participants before PHV and late maturers spent more minutes in MVPA than the other maturity groups. This supports the fact that maturation is a significant variable concerning PA participation. Hormonal fluctuations involved in puberty tend to create marked changes in body composition. Adolescents become taller and heavier and there is an increase in adipose tissue, especially in girls [42]. Lower proficiency in motor skills may also become present [28,41]. All these factors can depart adolescents from regular PA practice.

As expected there were also differences between sexes in time spent by PA intensity levels. Boys consistently spent more minutes in moderate, vigorous and very vigorous intensity levels. It´s a fact that boys are less sedentary and more active than girls at all ages [5,7,25,33] and girls seem to be associated with a lower involvement in PA, especially the ones that mature earlier [9,42]. Boys are usually more active and have more freedom to explore outdoors [25]. Moreover they seem to receive more encouragement from parents to practice PA when compared to girls [5].

Considering injury body area location descriptive data revealed that participants with lower limbs injuries when compared with participants with upper limbs injuries, spent more time in all PA intensity levels. Lower limbs injuries are often associated with overuse mechanisms [44] which in turn are associated with higher time spent in sports participation [8,10,41] (unpublished data).

Regarding injury types, participants who had strains or fractures spent more time in moderate PA intensity level than participants with sprains, but participants who had sprains spent more time in very vigorous PA intensity level. Sprains are highly related with traumatic mechanisms [38] due to joint stiffness and abnormal movement mechanics during growth [41]. Increased sprain injury risk may occur as participants exercise in very vigorous intensity levels [10].

Predictors of Injury Profile

As already addressed predictors were only found for injury body area location and injury type. Lower limbs injuries increased 1.02 times for unit increment (minute) of total time spent in MVPA when compared to upper limbs injuries. It´s recognized in the literature that adolescents are more likely to present overuse lower extremity injuries [44]. These kind of injuries result from the greater exposure and involvement of the lower chain in PA [8,10] (unpublished data). Moreover it´s a fact that motor performance and movement mechanics in this period may be compromised. If PA is performed in a repetitively mode, at moderate to high intensities, increased stress will be placed on those structures and tissues, that may not be able to produce an appropriate response [41] (unpublished data). Also as the subjects grow and become heavier the load on the lower limbs increases. In addittion, muscles may not follow the same longitudinal and transverse bone growth, producing as a consequence strength and flexibility instability, creating an environment that can lead to lower limbs injuries.

Injury type presented two predictors: time spent in moderate PA and bone age. The odds of having a strain or a fracture compared to having a sprain increased 1.04 times for unit increment (minute) of time spent in moderate PA. The nature of youth sports participation with longer periods of extensive training and participation in large numbers of competitive events may contribute to the increase of sports injuries [9,11,44]. Moreover specialized athletes, in order to achieve their goals, may push themselves harder and play despite pain [15,31,32] often not respecting the adequate resting periods for a developing child [9,15],. Likewise repetitive movements expose the neuromuscular system and musculoskeletal tissues to repeated load [41]. If sport specialization had already occurred only one set of motor patterns will be trained and enhanced environment for injury occurence [41]. Recent studies have emphasized the importance of recreational free play precisely because regular and diversified PA allows the development of motor skills that are effective in preventing injuries [11,15,16,19,31,32]. However a transition in PA behavior in adolescence has been observed [33]. A shift from unstructured free PA towards sedentary activities during leisure time makes sports club participation the more important contributor to daily time in MVPA [33] which can, as explained above, create favorable conditions for the occurrence of specific injuries. Also as already seen in a larger sample (unpublished data), strains and fractures are more likely to occur near PHV. Descriptive data showed that study participants were in their majority near or in PHV stage. The combination of higher time spent in moderate PA intensity and PHV may create the conditions to sprains and fractures occur. Fractures are usual during pubertal maturation due to deficits in bone mass [3] (unpublished data), and at this stage, there are more accidental and traumatic injuries during sports practice [3,45] (unpublished data). On the other hand, strains are more likely to occur in participants who had surpassed PHV recently. This condition makes them more vulnerable to excessive load [39] (unpublished data). Although after PHV tissue and structural dynamic equilibrium begins to be reached some degree of fragility still persists, especially in soft tissues (unpublished data). Subjects who have not developed some skills like strength, endurance and motor control may be at increased injury risk as they begin to spent more minutes in moderate PA [10].

Similar results were obtained for bone age. The odds of having a strain or a fracture compared to having a sprain decreased 1.7 times for unit increment (years) of bone age. As seen participants with lower biological ages are normally more engaged in sports practice which clearly increases exposure to risk. Also at these ages growth process and biological development starts and an unbalanced phase of motor control and tissue adaptations occur [9,15]. As aforementioned strains and fractures are common at this stage [16,41] (unpublished data). Increased vulnerability for traumatic and overuse injuries has been reported [41]. Besides these factors, in PA, maturing children and adolescents are not grouped according to their biological age [11,19]. Subjects are normally grouped by chronological age. Children of the same chronological age may vary considerably in biological maturity status which can make individual differences appear [4,20]. Athletes with higher biological ages perform better, are structurally and functionally stronger than the athletes with lower biological ages [41]. The direct confrontation between these two groups may represent a risk for injury [49]. Besides all this younger children still face another circumstance, they may not be cognitivly prepared to participate in highly structured PA . Children who are easily distracted and have a lower capacity for understanding may present a higher injury risk [10].

There weren't found meaningful associations between injury occurrence and injury rate and the evaluated predictors. Several studies have already discussed the association between injuries and higher intensity PA [24,43]. However considering the present results and previous studies [8,9], PA volume and level of sports participation seem to influence in a more significant way these two variables. Nonotheless the sample used in this study had limited dimensions and the PA intensities recorded were mainly from moderate level, which may not have been sufficiently discriminatory to evaluate if time spent in vigorous and very vigorous intensity levels increases the risk and the occurrence of injury.

CONCLUSION

Injury profiles in youth vary considering maturation and PA intensity, as seen in this original study. Children that reported higher time in MVPA presented higher injury risk for lower limbs injuries. As well younger children that spent more minutes in moderate PA presented a higher injury risk for strains and fractures. It's essential to master the actual benefits and disadvantages of sports participation at these ages, in order to adjust the best prevention methods. PA intensity combined with a maturing body may indeed create conditions to sports injuries become an issue. From health professional's point of view PA intensity levels in childhood should be approached with care and precaution, optimizing performance while minimizing injury. During adolescence it's clinically sensible to control and adjust training load (frequency, intensity or duration) and promote rest and recovery times. Risk associated with PA intensities and maturational variables still need to be clarified. These conditions have to be studied in future studies.

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CHAPTER 8

YOUTH SPORTS INJURIES ACORDING TO HEALTH RELATED QUALITY OF LIFE AND PARENTAL INSTRUCTION

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Youth Sports Injuries According to Health Related Quality of Life and Parental Instruction

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Abstract

Background: The relationship between sports injuries, health related quality of life (HRQoL) and parental instruction is still not clear so our aim was to determine sports injuries biosocial predictors in Portuguese youth.

Methods: Information about HRQoL, parental instruction and sports injuries was assessed via three questionnaires (KIDSCREEN-52, RAPIL II and LESADO) and filled by 651 subjects aged 10 to 18 years. Univariate analyses were used to verify significant differences between groups. Logistic, linear and multinomial regression analyses were used to determine significant biosocial predictors of injury, injury rate, injury type and body area injury location.

Results: Injury rate was higher in boys with lower scores in school environment dimension of KIDSCREEN-52 ($p = .022$) and in girls was higher in those with lower scores of moods and emotions dimension (p .001) and higher scores of self-perception dimension ($p < .001$). Also in girls, upper limbs injuries were associated with higher scores of moods and emotions dimension and spine and torso with lower scores ($p = .037$). Lower limbs injuries were associated with lower father's education and upper limbs ($p = .046$) and spine and torso ($p = .034$) injuries with higher father's education.

Conclusion: Sports injuries were related to several dimensions of KIDSCREEN-52 and parental instruction.

Keywords: Sports Injuries, Children and adolescents, Health Related Quality of Life, Parental instruction.

Introduction

Participation in physical activity involves a risk of injury that has a considerable public health impact [6]. Sports injuries are the major cause of morbidity among children and adolescents in developed countries [36]. They account for just over half of all injuries in secondary school children. There's still a lack of consensus on the relationship between health related quality of life (HRQoL) and risk of injuries [36], but extensive consequences to several social dimensions are already recognized [1]. They cause significant school and sport disruption and have important implications for the wider family [1]. Sports injuries are normally minor, causing limited physical and social disruption, but recently such injuries were reported as a major reason for unnecessary school absence and time off from parents' work bringing educational consequences for the child and economic costs to parents [1,11,22,30]. Injuries have also direct costs as a result of evaluation, treatment and rehabilitation [11]. In addition to the physical and financial costs, injured athletes during the growing years may experience unfavourable changes in body composition [32] and negative psychological consequences, including mood disturbance and lowered self-esteem [30]. Besides the negative consequences associated with inactivity and long term dysfunction health-related consequences associated with injury may have other, as yet unknown, sequelae that may affect areas of the adolescent's life, such as study habits, personal relationships, and risk for substance abuse [22].

The available evidence isn´t consensual regarding HRQoL. Adolescent athletes with self-reported injuries demonstrated lower HRQoL than their uninjured peers across a wide age range [21,22]. There is also clear evidence for the long-term effects of sport-related injuries [22]. Nevertheless, it had also been demonstrated in McLeod and colleagues work [22] a non significant difference in HRQoL perception between adolescent athletes with and without recent injuries. The reported injuries did not affect the injured adolescents' HRQoL perception. The injured group scored similarly to the population mean, which had already been seen in McAllister and colleagues work [21]. Their score (although not significant) was lower than their uninjured peers indicating that injury may cause after all some changes in their perceived roles. These findings may express the type of injuries reported by the sample (mainly sprains, strains and overuse musculoskeletal injuries) and the characteristics of the injuries, that were, very recent injuries. Also most of the injured athletes were still participating in their sport to some extent, therefore limiting the effect of significant changes on the mental health subscales and total score of HRQoL, reflecting the high-functioning nature of these athletes and insensitivity to differences resulting from predominantly minor injuries.

In recent years special attention has been paid to parental education and its relation to sports injuries. Education seems to be a more salient predictor of adolescent self-rated health status than income or the compound indicator SES [3]. Adolescents whose parents were more highly educated self-rated their health status better than adolescents whose parents have attained less formal education [3].

Additionally clinical data proved also that youngsters under psychological stress are more predisposed to injury and future musculoskeletal pain [8]. Therefore the aim of this study was to understand the importance of biosocial variables like HRQoL and parental instruction, as predictors of injury occurrence, injury rate, body area location and injury type in Portuguese children and adolescents.

Materials and Methods

The research protocol was in accordance with the Helsinki Declaration for scientific research involving human beings, and was approved by the Ethics Committee of the Faculty of Human Kinetics, University of Lisbon (President – Pedro Teixeira; CEFMH Approval Number - 50/2015). Before inclusion in the study all subjects' guardians gave their written informed consent.

KIDSCREEN-52, LESADO and Rapil II questionnaires were distributed to 651 participants, aged between 10 and 18 years, in four Portuguese schools. To assess HRQoL, KIDSCREEN-52 was used. HRQoL is defined as the individual's perception of their position in life in the context of culture and value systems in which they live and in relation to their goals, expectations, standards and concerns [15]. This self-reported questionnaire is based on the definition of Quality of Life (QoL) as a multidimensional construct covering physical components, emotional, mental, social and behavioural well-being and functioning [9]. KIDSCREEN-52 is validated in 13 European countries and is suitable for long term follow up measurement of HRQoL in children after injury since it meets the international quality standards [33]. It covers a large age range (8 to 18 years old), has good psychometric properties and covers the International Classification of Functionality content substantially [15]. An acceptable level of internal reliability for the Portuguese population (Cronbach's alpha = 0.80) was previously demonstrated. The KIDSCREEN-52 is completed according to a Likert scale from 1 to 5 points and consists of a general index of HRQoL in ten dimensions: Physical Well Being, Psychological Well Being, Moods and Emotions, Self-Perception, Autonomy, Parent Relation and Home Life, Financial Resources, Social Support and Peers, School Environment and Social Acceptance and Bullying. Permission to use this questionnaire was granted by KIDSCREEN group. The scores of KIDSCREEN dimensions are based on the Rasch model in order to avoid participant's exclusion due to missing data. The scores of Rasch scales were calculated for each dimension, transformed into t-values, according to the mean values and standard deviations from a European multinational sampling [33].

LESADO is also a self-reported questionnaire that gathers information about sports injuries profile. Comes from an extensive literature review on the topic and was adapted and based on epidemiological questionnaires used in Portuguese sports samples [6,24]. It was also provided a clear definition of sport injury, based in current epidemiological research [4] and time frame used was 6 months (September 2011 to March 2012), as recommended in retrospective studies [26].

Both KIDSCREEN-52 and LESADO were completed by each subject in a quiet and comfortable space, prepared specifically for this purpose, supervised by an investigator who followed and clarified all doubts preventing the possibility of bias and interpretation difficulties associated with low literacy skills [28]. It was required about 20 minutes to complete each questionnaire. When children report their own injuries they are able to give a detailed account of the circumstances of the injury event, together with other lifestyle details [36]. Adolescents also have strong and reliable perceptions about their relative social standing [31] and school age is considered a milestone from which children are already able to understand and report reliable answers on the issues of HRQoL [25].

The Biosocial Questionnaire RAPIL II is a parent´s self-reported instrument and it was used to measure biosocial variables. It´s been used in Portugal in large epidemiological studies [10,35] and provides information about the daily PA habits, academic and family related information.

The statistical analysis was conducted using SPSS 22.0 software (SPSS Inc., Chicago, IL, USA) and a significance level of 5% was considered. Descriptive statistics was used to determine the sample characteristics regarding biosocial variables and injury profile. Chi-square test of homogeneity, t-test for independent samples, Kruskal-Wallis test and ANOVA were used to verify if there were significant differences between groups. Stepwise logistic, linear and multinomial regression analyses were used to identify the significant predictors, among a set of biosocial variables, of injury occurrence, injury rate, and injury type and body area location, respectively. The dependent variables were injury occurrence (0 = no and 1 = yes), injury rate, injury type (0 = strain, 1 = sprain, 2 = fracture) and body area injury location (0 = lower limbs, 1 = upper limbs, 2 = spine and trunk). The evaluated predictors for each sex were parental instruction of each progenitor (0 = primary, 1 = basic, 2 = high school, 3 = graduated, 4 = master e Phd) and HRQL (0 = Physical Well Being, 1 = Psychological Well Being, 2 = Moods and Emotions, 3 = Self-Perception, 4 = Autonomy, 5 = Parent Relation and Home Life, 6 =Financial Resources, 7 = Social Support and Peers, 8 = School Environment, 9 = Social Acceptance and Bullying and 10 = KD total score index).

Results

A total of 247 subjects (37.9%), from the 651 that answered the questionnaire, reported experiencing a sports injury during the previous 6 months. Considering the analysis by sex, 143 of 342 boys reported injury (41.8%) and 104 of 309 girls reported injury (33.7%). The most injured body areas were lower limbs (53.8%), followed by upper limbs (29.0%). Spine and torso accounted with 11.5%. The type of injuries found was strains (33.7%), sprains (27.1%) and fractures (23.1%). Considering the sample that reported a sports injury, the average injury rate was 11.8 per 1000h of PA exposure (M = 11.8; SD = 8.1). Female subjects had a higher average injury rate (*M* = 13.6; *SD* = 9.2) than males (*M* = 10.4; *SD* = 6.9) ($t(183.3) = -3.013$, $p = .003$). Looking at the descriptive data of table 1 we can see that HRQoL perception of the sample is mainly concentrated in average scores. Boys reported higher values of QoL perception ($X^2(2) = 6.515$, $p = .039$) than girls. As for parental education the vast majority had a high school or a bachelor's degree. Injury rate that mainly translates injury risk, increased slightly in the lowest QoL perception scores and parental education groups. As to the body area injury location, spine and trunk injuries seem to be more reported by subjects that presented lower values of HRQoL perception. Regarding injury type, we noticed a homogeneous distribution by groups.

Injury Occurrence

There weren´t found significant results for both sexes.

Injury Rate

For boys (table 2) only school environment dimension of KIDSCREEN-52 was included in the final linear regression model ($F(1,124) = 5.361$, $p = .022$; $R^2 = .041$). Injury rate was higher in lower scores of that dimension ($r = -.204$, $p = .022$). As for girls the final linear regression model (table 2) included moods and emotions and self-perception dimensions of KIDSCREEN-52 ($F(2,96) = 7.201$, $p = .001$; $R^2 = .130$). Injury rate was higher in lower scores of moods and emotions dimension ($r = -172$, $p = .088$) and in higher scores of self-perception dimension ($r = .161$, $p = .110$).