Original Article

Impact of sports participation on incidence of bone traumatic fractures and health care costs among adolescents: ABCD – Growth Study

ABSTRACT

Objective: To analyze the risk of bone traumatic fractures according to the engagement in sports, as well as to identify the potential impact of sports participation and traumatic fractures on health care costs among adolescents. *Methods:* This is a longitudinal 12-months follow-up study of 285 adolescents of both sexes in Brazil. We assessed the occurrence of traumatic fractures and health care services (hospitalizations, medicine use, medical consultations and exams) by phone contact every single month for 12 months. Adolescents were divided into four groups according to sport characteristics: non-sport (n= 104), non-impact sport (swimming [n= 34]), martial arts (n= 49 [judo, karate, kung-Fu]) and impact sports (n= 98 [track-and-field, basketball, gymnastics, tennis, and baseball]). *Results:* The incidence of new fractures was 2.1%. The overall costs accounted during the 12-month follow-up were U$ 3,259.66. Swimmers (US$ 13.86) had higher health care costs than non-sport (US$ 1.82), martial arts (US$ 2.23) and impact sports (US$ 2.32). *Conclusion:* swimming seems to be related to higher health care costs among adolescents.

Keywords: Athletic Injuries; Economics; Bone; Pediatrics

1. Introduction

Physical activity has been pointed out as an important behavior leading to better health and growth among pediatric groups [1]. Sports participation -a subset of leisure physical activity- is the most relevant manifestation of exercise during adolescence, being a valuable way to meet physical activity guidelines. In terms of health benefits, sports participation is capable of promoting cardiovascular, metabolic and psychological aspects during pediatric ages more significantly than other physical activity domains [1–4].

Another health aspect linked to sports participation is its osteogenic effect on skeleton, which has been widely investigated in adolescence, mainly due to its potential role in the prevention of osteoporosis later in life [2,5–7]. However, even with sports participation in early life improving bone parameters during adulthood, the osteogenic effect creates a complicated situation, mainly because mechanical load generated during sports (which is essential to estimate bone formation) [2,8] can lead to stress and traumatic fractures.

It is not possible to ignore the fact that physical actions embraced by different sports (e.g. running, jumping, physical contact with other players) can increase the risk of any adverse event, such as injuries and fractures. An American survey investigating pediatric orthopedic injuries showed that the highest total hospitalization charges were among children with femur fractures and adolescents with vertebral fractures [9]. A study with rugby players found that 2% of the players need medical care after the tournament and for these players, average treatment costs were high (US$ 731 per visit), with fractures being the most expensive type of injury [10].

However, recent studies also have shown that long-term exercise programs improve bone mass and bone size among children and adolescents, without affecting the fracture risk

[11–13]. Actually, evidence confirms that participation in ball sports promote supplementary bone health than other sports, reducing the risk of fractures [8,13].

In a background in which public health campaigns are developed to promote sports participation among pediatric groups targeting health promotion, the burden of sports participation and its side effects (e.g. injuries and fractures) on economic aspects need to be considered as well. Among adults, the economic benefits of sports participation seem to be easier to identify than in pediatric groups, mainly because chronic conditions linked to physical inactivity are usually observed in this age group [14].

On the other hand, this relationship among the pediatric population is far from being clear because the dynamics of health care costs in both age groups differ [15]. For instance, in pediatric groups, the impact of sports participation on health care outcomes are more difficult to identify than in adults, mainly because the main health benefits generated by sports participation are observed later in life [6,16]. Therefore, potential economic benefits of sports participation might be overshadowed by the costs generated by the treatment of outcomes related to sports participation, such as fractures, injuries, and upper respiratory infections (commonly observed in water sports) [15,17,18].

Therefore, this longitudinal study aimed to analyze the risk of traumatic fractures according to the engagement in sports with different levels of physical impact, as well as to identify the potential impact of sports participation and traumatic fractures on health care costs among adolescents.

2. Methods

The longitudinal research entitled "Analysis of Behaviors of Children During Growth" (ABCD – Growth Study) is an ongoing study dedicated to identifying the impact of sports participation on different health aspects of adolescents, including health care costs. The present study is part of the ABCD – Growth Study, which is being carried out in Presidente Prudente (~200,000 inhabitants and human development index 0.806), western state of São Paulo, Brazil. Data collection and analyzes were performed at Laboratory xxxxxxxxxxxxxxx in 2017 (baseline) and 2018 (12 months follow-up). The ethics committee of xxxxxx approved the study (process number xxxxxxxxxx). All the parents/guardians signed the consent form, and the coaches responsible for the adolescents engaged in organized sports signed an authorization form too. Adolescents signed a form agreeing to participate in the longitudinal study.

The sample was composed of 285 adolescents of both sexes (202 boys and 83 girls) who were contacted by the researchers in eleven schools and sports clubs located in the metropolitan region of the city (the contact has been previously authorized by the principals [school] and coaches [sports clubs]). All 285 adolescents in all eleven places were invited, considering the inclusion criteria 1) 10-18 years-old, 2) parents' consent form signed, 3) if contacted in any sports club, at least one year of training experience in order to characterize a consistent engagement; if contacted in any school unit, at least one year without regular practice of sport or exercise.

The occurrence of traumatic fractures was assessed at baseline and during the 12-months follow-up period. At baseline, the participants were asked the following yes or no question: “During the past 12 months, have you experienced any broken bones?”[13]. During the 12-months follow-up, once a month the researchers contacted the adolescents by phone to register any occurrence of traumatic bone fracture, as well as the bone broken and date of the event.

Health care costs were assessed during 12 months of follow-up by the researchers throughout monthly phone contacts with adolescents and their parents/legal guardians. Researchers asked adolescents monthly about the use of medication (name and dosage), appointments (medical specialties [e.g. pediatrician, general practitioner, ophthalmologist, orthopedist, ear, nose and throat specialist, dermatologist, pulmonologist, emergency doctor, physiotherapist, speech therapist, psychotherapist, occupational therapist, homeopath and others), hospitalizations and laboratory tests. The price of each of the components of health care services was collected from pharmacies (when bought by the participant), private health care plan (when paid by the participant) and National Health Service (when provided by the government) [14,19]. In the case of pharmacies, three independent researchers contacted three different pharmacies in the metropolitan region of the city, and the average price of the medicine was considered. The prices were computed in Brazilian currency (Real [R$]), and all these values converted into American dollar (US$), using the average quotation of the 12 months of follow-up (US$ 1.00 equal to R$ 3.193).

In terms of sports participation, adolescents were divided into four groups according to sport characteristics: non-sport (n= 104), non-impact sport (swimming [n= 34]), martial arts (n= 49 [judo, karate, kung Fu]) and impact sports (n= 98 [track and field, basketball, gymnastics, tennis, and baseball]) [5,20].

In a face-to-face interview, the adolescents reported sex and birthday (chronological age). Adolescents engaged in any sport reported the number of days per week involved in practice, as well as the time (in minutes). Coaches confirmed this data.

Body weight (kg) was measured using a digital scale (Filizzola PL 150; Filizzola Ltda, São Paulo, Brazil) and height (cm) was measured using a stadiometer with a precision of 0.1 cm. Both measurements were collected using standard protocols. Analysis of the sitting height and length of the legs were performed to calculate the maturity offset, which denotes the time (years) from/to the age at the peak height velocity (PHV), an indicator of biological maturation [21]. PHV is an important event of the biological maturation process, which can influence body composition and bone variables.

Body fatness (in percentage [%]), and BMD (g/cm2) of the whole body were assessed using a dual-energy x-ray absorptiometry (DXA) scanner (Lunar DPX-NT; General Electric Healthcare, Little Chalfont, Buckinghamshire, UK) with GE Medical System Lunar software (version 4.7). DXA measurements were performed in the morning after a light breakfast, and the scanner quality was tested by a trained researcher before each day of measurement, following the manufacturer's recommendations. The participants wore light clothing, without shoes and remained in the supine position on the machine (approximately 15 min).

The self-report of musculoskeletal symptoms in any body segment (neck, shoulder, upper back, low back, elbows, wrists/hands, hips/thighs, knees and ankles/feet) over the last week before the face-to-face interview has been assessed using the Nordic Musculoskeletal Questionnaire [22]. Finally, the adolescents' blood was collected by a nurse in an independent laboratory (which meets all the guidelines of the Brazilian Ministry of Health), and C-reactive protein (CRP) levels (mg/L) were assessed as an inflammatory marker.

Descriptive statistics were expressed in values of percentage (%), mean, median, 95% confidence interval (95%CI) and interquartile range (IR) because some data showed non-normal distribution. Mann-Whitney test was used to compare continuous data according to the presence of traumatic fractures (**Table 1**). Kruskal-Wallis test was used to compare health care costs according to different sports.

Some variables adjusted multivariate models (general linear model and cox regression), while these variables were identified as potential correlates due to its impact on either health care costs or fractures [23,24]. We assessed the risk of traumatic fractures according to the sports participation and controlling for covariates (sex, age, body fatness, somatic maturation, BMD and CRP) using Cox Regression (Hazard Ratio [HR] and its 95%CI). Analysis of covariance (ANCOVA) was used to investigate the relationship between overall health care costs and sports participation adjusted by sex, age, PHV, BMD, body fatness, CRP, occurrence of fractures, previous engagement in sports and minutes of practice per week (**Table 2**). In ANCOVA model, heath care costs were converted into a logarithm transformed variable due non-parametric distribution, Levene's test assessed how fit the ANCOVA model was (model was adequately fit) and measures of effect-size were expressed as Eta-squared values (ES-r). Finally, a generalized linear model using gamma distribution with a log-link function ([GLM-Gamma], expressed as β and its 95%CI) has been created in which overall health care costs was the dependent variables and all other variables were treated as independent variables (**Table 3**). GLM-Gamma multivariate model considered only significant covariates at univariate analysis (Pearson correlation) and values of relative chi-squared (X^2) were adopted as measures of goodness-of-fit of the model. Statistical significance was set at $p<0.05$ and all analyzes were performed using BioEstat software (version 5.2 [BioEstat, Teffe, Brazil]).

3. Results

The sample was composed of 202 boys and 83 girls. Adolescents engaged in sports trained an average of 112.5 minutes per day (95%CI: 104.6 to 120.4) in 2.9 days per week (95%CI: 2.7 to 3.2). There was the incidence of six new fractures during the follow-up period (n= 1 in the elbow, n= 2 in the toe, n= 1 in radius and n= 1 in right arm; n= 1 in the finger). There was no traumatic fracture caused by a car accident during the 12-month follow-up. The overall costs accounted during the 12-month follow-up were U$ 3,259.66 (medication: US$ 1,671.80 [52.9%], appointments: US$ 948.46 [28.7%] and laboratory tests: US$ 639.41 [18.4%]). When comparing the adolescents according to the incidence of new fractures, the group with fracture presented significant higher health care costs (**Table 1**). Sports participation did not show any significant association with the occurrence of traumatic fractures during 12-months [Non-sport HR= 1.00; Swimming HR= 1.58 (95%CI: 0.13 to 19.06); Martial arts HR= 2.97 (95%CI: 0.37 to 23.30); Impact sports HR= 1.24 (95%CI: 0.15 to 10.21)].

When splitting the groups down by sport, track and field [median: US$ 4.45 (IR: 27.67)], gymnastics [median: US$ 11.08 (IR: 23.90)], judo [median: US$ 4.56 (IR: 6.96)], and swimming [median: US$ 24.98 (IR: 46.50)] presented higher costs when compared to the non-sport group [median: US$ 0.31 (IR: 0.0)] [Kruskal-Wallis test with p-value= 0.001]. Karate [median: US$ 0.31 (IR: 6.40)], kung-Fu [median: US$ 0.31 (IR: 4.49)], tennis [median: US$ 0.31 (IR: 12.41)], basketball [median: US$ 0.31 (IR: 0.0)] and baseball [median: US$ 0.31 (IR: 0.55)] did not show significant differences for costs when compared to the non-sport group.

Even after adjustment by confounders, swimmers (US$ 13.86 [95%CI: 8.55 to 22.54]; p-value= 0.001) had higher health care costs than non-sport (US$ 1.82 [95%CI: 1.35 to 2.47];

p-value= 0.001), martial arts (US$ 2.23 [95%CI: 1.44 to 3.45]; p-value= 0.001) and impact sports (US$ 2.32 [95%CI: 1.68 to 3.19]; p-value= 0.001) (**Table 2**).

Swimmers accumulated an average US$ 2.09 more health care costs than other adolescents of this cohort (independently of the engagement in other sports). Moreover, girls accumulated an average US$ 0.45 less health care costs than boys, while every single fracture sustained by the adolescent accounted an average US$ 1.06 more health care costs (**Table 3**). The final model was significant (p-value= 0.001) and satisfactorily adjusted (goodness-of-fit).

4. Discussion

In this longitudinal study, we found that engagement in weight-bearing sports did not increase the risk of fractures, while adolescents engaged in swimming (mainly), track and field, gymnastics, and judo presented higher health care costs when compared to the non-sport group.

The incidence of new fractures during the follow-up period was low (2.1%), which is similar to other longitudinal studies considering young athletes [13, 25]. In statistical terms, the low incidence of fractures might be one of the reasons behind the absence of significant associations between sports participation and traumatic fracture. However, this information denoting the absence of significant associations between sports participation and traumatic fractures seems relevant because sport injuries persist in adulthood [26].

Even with no association with sports participation, we found that the incidence of new fractures significantly increased health care costs among adolescents. Previous survey reported similar findings, in which the occurrence of fractures is the cause of high health care costs in adolescents engaged in sports like rugby [10]. It is also relevant to identify that the incidence of new fractures affected significantly all components of overall health care costs (medication, appointment, and tests), reflecting the steps of treatment and healing of the traumatic event. Moreover, it is pertinent to recognize that small changes in training (e.g. replacing regular warm-up by neuromuscular training) are able to mitigate costs attributed to sport injuries [17], denoting the relevance of having highly qualified coaches and trainers assisting the athletes.

Another variable affecting costs among these adolescents was sex, in which girls accumulated higher health care costs than boys. Among adults, women usually accumulate more annual health care costs than men [14], mainly due to social and cultural aspects. This finding is supported by the fact that women are more prone to be regularly engaged in preventive medicine than men since early age (e.g. birth control, gynecologist) [27]. Therefore, cost-effective interventions involving exercise targeting the mitigation of costs among adolescents should be designed focusing on sex-related particularities, because the dynamic of economic variables seems to be sex-dependent.

Regarding health care cost among different sports, we found that track and field, gymnastics, judo, and swimming presented significant higher costs when compared to the non-sport group. In all sports above mentioned, this finding could be justified by the high amount of repetitive movements required by these sports during practice, plus the high volume of training and inflammation, which could lead to damage to the muscle and joints and weakening of the immune system [28]. Moreover, each of these sports have its inherent aspects that could affect health care costs. For example, judo athletes are constantly reducing body weight using dehydration and food restriction in order to be able to compete in specific weight classes (sometimes using medicines for that), leading to harmful health implications (e.g. anxiety, eating disorders) which have worse consequences in young judo athletes [29]. Eating disorders and anxiety symptoms are outcomes commonly observed in gymnasts as well [30] due to the necessity of having less body weight for better performance. Moreover, symptoms of anxiety and depression are identified in young athletes of track and field [31]. All these health outcomes happening during a calendar year might influence significantly health care costs among these adolescents.

Swimmers accumulated the highest health care costs in this study. In fact, the consumption of medicines to relieve cold symptoms was the most frequently reported by our swimmers. Concerning the highest health care costs among swimmers, it could be explained by the highest training load observed among this particular group, as well as the humid environment where practice takes place [15,18]. Similarly, a 4-year longitudinal study found that the risk of upper respiratory tract and pulmonary infections and muscular affections among swimmers increased significantly with higher training loads [32]. Additionally, it is already established that swimming does not prevent fractures despite absence of impact (in our study there was 1 fracture among swimmers, which happened in activities not related to swimming) [5,13].

In this survey, some sports increased health care cost among adolescents, but health professional should interpret these findings with caution. First, most of health care costs observed in this study came from primary care services, while more complex health procedures were not observed. Sports participation prevent the development of a large variety of diseases that significantly increase costs in a more complex level, such as childhood obesity and high blood pressure. Second, even with higher costs among adolescents engaged in some sports, the amount of money accounted over the last 12 months was low (U$ 3,259.66), while in adults, the mitigation attributed to physical activity in developing settings is accounted in US$ 26 million [33]. Finally, sports participation tracks from adolescence to adulthood more than exercise [34], and affects health in adolescence and adulthood [3,16], representing a huge potential to mitigate health care costs throughout life. However, it is also relevant to highlight that some sports had similar costs to the non-sport group (e.g. basketball, baseball, karate and tennis), denoting potential alternatives to improve health aspects in pediatric groups with apparently low impact on health care costs.

National Health Service in Brazil is an organizational structure similar to the observed in other nations with universal health care, such as UK, New Zealand, Spain, Australia and Canada. Therefore, extrapolations of our findings would be not impossible to these scenarios (of course, accounting due particularities in each nation). However, the most relevant aspect of our study is not to describe absolute monetary values, but mainly patterns of this barely explored aspect of sports participation, which happens for sure in all nations where sports participation is stimulated among pediatric groups.

The assessment of health care costs among these adolescents is a challenging aspect of this survey [14,19], but also a strong methodology aspect. As limitations, we recognize the absence of clinical records to assess more details about the traumatic fracture reported, as well as the absence of data about stress fractures. Additionally, the use of health care services was self-reported monthly by the participants, which it is prone to bias recall, even being assessed every month. Lastly, the short period of follow-up could be considered a limitation.

5. Conclusions

In summary, sports participation did not increase the risk of fracture, while sports participation (mainly swimming), traumatic fracture and gender were determinants of health care costs among these adolescents.

Practical implications

- Engagement in sports raised the health care costs among adolescents.
- The amount of money attributed to sports participation was few, while its maintenance has potential to mitigate costs throughout life, preventing the development of a large variety of diseases that significantly increase costs in a more complex level.
- Engagement in sports should be encouraged and the health care costs of those participants closely monitored.
- **Conflict of interest**

None

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Table 1. General characteristics according to the occurrence of traumatic fracture in adolescents (ABCD – Growth Study; n= 285).

	Traumatic Fracture 12 months*		
	No (n= 279)	Yes (n= 6)	
Independent variables	Median (IR)	Median (IR)	*p*-value**
General information			
Sex (boys / girls)	197 / 82	5 / 1	---
Ethnicity (White [%])	53.4%	50.0%	0.289
Age (years)	14.88 (3.5)	16.89 (3.3)	0.055
Body mass (kg)	57.8 (18.6)	62.5 (16.9)	0.170
Height (cm)	167.3 (15.9)	172.6 (12.2)	1.110
BMD (g/cm^2)	1.122 (0.169)	1.137 (0.144)	0.783
BMC (g)	2,496.8 (812.1)	2,690.2 (855.6)	0.291
Body fatness (%)	21.4 (16.3)	13.85 (8.8)	0.067
Sports (min/wk)	240 (720)	360 (607.5)	0.490
Maturity offset (years)	1.44 (2.14)	2.62 (2.23)	0.092
C-reactive protein (mg/L)	2.50 (2.2)	2.15 (5.2)	0.779
MSK last week (sum)	0.0 (1.0)	0.0 (1.5)	0.962
Health care costs (US$)			
Medicines	0.31 (4.64)	12.43 (26.40)	**0.028**

Appointments	0.31 (0.00)	10.49 (12.72)	**0.007**
Tests	0.31 (0.00)	3.13 (6.39)	**0.001**
Overall	0.93 (8.96)	23.99 (29.12)	**0.005**

*= incidence of new traumatic fractures that happened during the 12-month follow-up; **= Mann-Whitney test; IR= interquartile range; BMD= bone mineral density; BMC= bone mineral content; MKS= musculoskeletal symptoms.

Table 2. Overall health care costs (US$) in adolescents according to sports participation (ABCD – Growth Study; n= 285).

Health care costs	Non-sport (n= 104) Mean (95%CI)	Martial Arts (n= 49) Mean (95%CI)	Impact Sports (n= 98) Mean (95%CI)	Swimming (n= 34) Mean (95%CI)	*Sport participation* *p*-value (ES-r [magnitude])
ANCOVA $_{\text{crude model}}$					0.001 (0.186 [High])
Overall $_{\log10}$	0.270	0.429	0.343	1.189 [a,b,c]	
	(0.158 to 0.383)	(0.271 to 0.588)	(0.229 to 0.457)	(0.916 to 1.455)	
ANCOVA $_{\text{adjusted model}}$*					0.001 (0.186 [High])
Overall $_{\log10}$	0.262	0.350	0.366	1.142 [a,b,c]	
	(0.131 to 0.393)	(0.161 to 0.539)	(0.227 to 0.505)	(0.932 to 1.353)	
Overall (US$)**	1.82	2.23	2.32	13.86	---
	(1.35 to 2.47)	(1.44 to 3.45)	(1.68 to 3.19)	(8.55 to 22.54)	

95%CI= 95% confidence interval; ES-r= eta-squared; ANCOVA= analysis of covariance; log10= variable converted into logarithm base 10; a= denotes difference (*p*-value <0.05) compared to non-sport; b= denotes difference (*p*-value <0.05) compared to Martial Arts; c= denotes difference (*p*-value <0.05) compared to Impact sports;
*=ANCOVA adjusted by sex (ES-r= 0.020 [p-value < 0.05]), age (ES-r= 0.007), peak of height velocity (ES-r= 0.003), whole body bone mineral density (ES-r= 0.001), body fatness (ES-r= 0.001), C-reactive protein (ES-r= 0.015), fracture 12-months follow-up (ES-r= 0.019 [p-value < 0.05]) and musculoskeletal symptoms (ES-r= 0.004).
**= logarithm variable converted back into natural number by exponentiation.

Table 3. Relationship between health care costs and its potential correlates among adolescents (ABCD – Growth Study; n= 285).

	Dependent variable: Overall Health Care Costs (US$)				Model - Goodness-of-fit	
	Pearson		GLM - Gamma		x^2 relative	
Independent variables	correlation (*r*)	p-value	β (β 95%CI)	p-value	(x^2 / *df*)	Satisfactory
					4.512	<5.0
Sex (girls)*	**-0.161**	**0.004**	**-0.459 (-0.798 to -0.121)**	**0.008**		
Age (years)	0.130	>0.050	---	---		
Maturation (years)	-0.113	>0.050	---	---		
BMD (g/cm^2)	0.019	>0.050	---	---		
Body fatness (%)	-0.006	>0.050	---	---		
CRP (mg/L)	0.110	>0.050	---	---		
Fractures (yes/no)	**0.171**	**0.007**	**1.066 (0.001 to 2.130)**	**0.049**		
MKS (number of events)	-0.058	>0.050	---	---		
Sport (swimming)**	**0.423**	**0.001**	**2.091 (1.617 to 2.564)**	**0.001**		

X^2= chi-squared test; *df*= degree of freedom; 95%CI= 95% confidence interval; BMD= bone mineral density; MKS= musculoskeletal symptoms; CRP= C-reactive protein; *= dichotomous variable (girls= 0 and boys= 1); **= dichotomous variable (non-sport and other sports= 0 and swimming= 1).