INTRODUCTION

Medical School is a highly demanding course with potential drawbacks for students. Rates of depression and anxiety disorders are higher amongst medical students than among their nonmedical counterparts, and problems such as burnout and substance abuse are more frequent. Growing evidence that physical exercise could be an option in facing these problems exist. Participating regularly in a group fitness classes, in opposition to exercising alone or not at all, can lead medical students to decrease their perceived stress and increase their the physical, mental, and emotional quality of life. In Brazil, medical schools have a strong tradition in competitive sports tournaments. In addition to full-term classes and academic activities, medical students also participate in weekly practices and games in several sports modalities. Despite bringing several benefits to their quality of life, physical activity is a risk factor for musculoskeletal injuries.
The knowledge and surveillance of sports injuries are key components for preventing these events. According to van Mechelen, Hlobil, and Kemper, to prevent sports injuries, a four-step procedure should be followed: 1) identify the problem; 2) establish cause and mechanism; 3) develop, evaluate, and implement interventions; and 4) reevaluate these strategies through continuous surveillance. The purpose of this study was to evaluate the injury rate and the nature of sports injuries in medical students, as well as the risk factors involved.

METHODS
All student-athletes from the University of São Paulo Medical School (a 6-year course), Brazil, integrated in at least one of the six team sport modalities (soccer, rugby, indoor soccer, handball, basketball, and volleyball) in 2017 were included, totaling 218 participants. An appropriate institutional review board approved the project (CAPPesq 3.044.669 - 28/11/2018) and each participant provided written informed consent before participation. The study is in accordance with the Helsinki Declaration of 1975, which was revised in 1983.

Data on injuries and exposures for the 2017 season were collected separately. Regarding exposures, a form summarizing the number of practices and games and the average number of participants for each activity were submitted weekly by each team through Google forms based on the National Collegiate Athletic Association (NCAA) exposure report (Appendix 1). The authors collected data regarding injuries retrospectively, after the last practice or game of the 2017 season, based on the NCAA questionnaire (Appendix 2). Demographic data on age, gender distribution, year of medical school, and number of sports practiced were also collected at the end of the season.

A reportable injury had to meet the following criteria: 1) injury occurred as a result of participation in a university practice or game; and 2) injury resulted in restriction of the student-athlete participation or performance, regardless of time loss. Exposure was defined as one athlete participating in one practice or one game (athletes-exposure, A-E). Data on injury mechanisms (non-contact, other contact, player contact, and unknown), site of injury by body part, head and neck, upper limbs, torso and back, lower limbs, and other system), and severity of injury were analyzed as percentages. Injuries that resulted in at least 21 days away from sports activities were classified as severe.

A cross-sectional analysis was performed after injury and exposure data compilation. The analysis includes a comparison of injury rates in three categories: sports event (game vs. practice), year of medical school (junior athletes 1st-3rd year vs. senior 4th-6th year) and the number of sports practiced (single-sport athletes vs. multi-sports athletes). Multi-sports athletes were those integrated in at least two sports modalities. Injury rates were expressed as the number of injuries per 1000 A-E, with a confidence interval of 95%. For comparison between injury rates, the chi-squared test was used, with p-value < 0.05

RESULTS
Sample characteristics
In total, 218 student-athletes, from the six-year medical course, were included. 57.3% were men and 53% were enrolled from 1st to 3rd year, with a mean age of 22.51 (± 2.6) years. 159 (73%) were included. 57.3% were men and 53% were enrolled from the number of injuries per 1000 A-E,6 with a confidence interval of at least two sports modalities. Injury rates were expressed as percentages. Injuries accounted for the most injuries. The incidence of ankle sprain was 0.39 per 1000 A-E (95% CI = 0.14-0.63). The authors collected data regarding injuries retrospectively, after the last practice or game of the 2017 season, based on the NCAA questionnaire (Appendix 2). Demographic data on age, gender distribution, year of medical school, and number of sports practiced were also collected at the end of the season.

A reportable injury had to meet the following criteria: 1) injury occurred as a result of participation in a university practice or game; and 2) injury resulted in restriction of the student-athlete participation or performance, regardless of time loss. Exposure was defined as one athlete participating in one practice or one game (athletes-exposure, A-E).

Data on injury mechanisms (non-contact, other contact, player contact, and unknown), site of injury by body part, head and neck, upper limbs, torso and back, lower limbs, and other system), and severity of injury were analyzed as percentages. Injuries that resulted in at least 21 days away from sports activities were classified as severe.

A cross-sectional analysis was performed after injury and exposure data compilation. The analysis includes a comparison of injury rates in three categories: sports event (game vs. practice), year of medical school (junior athletes 1st-3rd year vs. senior 4th-6th year) and the number of sports practiced (single-sport athletes vs. multi-sports athletes). Multi-sports athletes were those integrated in at least two sports modalities. Injury rates were expressed as the number of injuries per 1000 A-E, with a confidence interval of 95%. For comparison between injury rates, the chi-squared test was used, with p-value < 0.05

Sample characteristics
In total, 218 student-athletes, from the six-year medical course, were included. 57.3% were men and 53% were enrolled from 1st to 3rd year, with a mean age of 22.51 (± 2.6) years. 159 (73%) integrated a single sport modality, whereas 59 (27%) were multi-sport athletes.

Number of injuries
Among the 218 student-athletes, 118 (54%) suffered at least one injury during the season. Among those, 72% (85) suffered just one injury, 23% (27) suffered two injuries, 3.2% (5) suffered three injuries and 0.6% (1) suffered four injuries. Altogether, in 2017, 25,622 exposures and 158 injuries were totaled.

Game and practice injury rates
The game injury rate (15.18 per 1000 A-E, 95% CI = 10.96-19.40) was 3.21 times higher than the practice injury rate (4.72 per 1000 A-E, 95% CI = 3.8-5.6) (Table 1). These rates equal one injury every 3.3 games and 1 injury every 10.6 practices for a team of 20 participants, across all sports.

| Table 1. Comparison of injury rates in three categories: Sports event, Year of Medical School, and Number of Sports Practiced. |

| Injury rate per 1000 A-E, (95%IC) | p |
|-----------------------------------|---|
| **Sports event**                  |   |
| Game                              | 15.18 (10.96-19.40) | < 0.001 |
| Practice                          | 4.72 (3.8-5.6)     |       |
| **Year of medical school**        |   |
| Juniors (1st-3rd year)            | 7.58 (6.11-9.06)   | < 0.001 |
| Seniors (4th-6th year)            | 4.49 (3.26-5.73)   |       |
| **No. of sports practiced**       |   |
| Single-sport athlete              | 4.49 (3.51-5.47)   | 0.002  |
| Multi-sport athlete               | 10.69 (8.22-13.17) |       |

Distribution of injuries by body part
Figure 1 shows the distribution of injuries by body part. In both practices and games, more than 80% of the reported injuries were located in the lower limbs. Ankle (24.7%) and knee (14.6%) accounted for the most injuries. The incidence of ankle sprain was 1.40 per 1000 A-E (95% CI = 0.93-1.87) and incidence of anterior cruciate ligament (ACL) tear was 0.39 per 1000 A-E (95% CI = 0.14-0.63).

Injury mechanism
Figure 2 shows the injury mechanisms in relation to practice and game. The mechanism involved in most injuries in games was player contact (51%) and in practice was non-contact (53%).

![Figure 1. Distribution (percentages) of injuries by body part for games and practices for 6 sports in 2017.](image_url)

![Figure 2. Distribution of injury mechanisms in relation to practice and game.](image_url)
Multisports athletes’ injury rate (10.69 per 1000 A-E, 95%IC 8.22-13.17) was 2.40 times higher than single sports injury rate (4.49 per 1000 A-E, 95%IC = 3.51-5.47), across all sports (Table 1).

Junior x seniors injury rates
Junior student-athletes (1st – 3rd year) injury rate (7.58 per 1000 A-E, 95%CI = 6.11-9.06) was 1.68 times higher than senior student-athletes (4th – 6th year) injury rates (4.49 per 1000 A-E, 95%CI = 3.26-5.73), across all sports (Table 1).

Time loss
The mean time loss was 40.1 days (95%CI = 30.62-49.59). There was a high incidence of severe injuries (48%). The knee accounted for most of the severe injuries (25.9%) followed by leg and ankle (20.7%), and shoulder (14.2%).

Injury rates by sport
As shown in Figure 3, the highest injury rates were: men’s indoor soccer (8.75 per 1000 A-E), men’s basketball (8.72 per 1000 A-E), and rugby (8.45 per 1000 A-E).

DISCUSSION
This study analyzes the injury rate and nature of sports injuries in medical students. Although enrolled in a high demanding course with 6 years of duration and full-term classes, medical students engage in weekly practices and competitive sports tournaments in Brazil. We found high rates of game and practice injuries (15.18 per 1000 A-E, 95%CI = 10.96-19.40) or one injury every 3.3 games and 4.72 per 1000 A-E, 95%CI = 3.8-5.6 or 1 injury every 10.6 practices for a team of 20 participants). A retrospective analysis of 396 student-athletes – including medical students – conducted by our group for the 2013 season, found similar rates.7 The sudden increase in physical demand, considering that most students lead a sedentary lifestyle prior to entering Medical School, may explain the higher incidence of injuries in junior students (1st – 3rd years) compared with seniors (4th – 6th years), 7.58 per 1000 A-E 95%CI = 6.11-9.06 and 4.49 per 1000 A-E 95%CI = 3.26-5.73, respectively. A Chinese study with university athletes identified freshman students as a risk group for sports injuries.8 These findings reinforce the importance of an adequate pre-participation assessment as well as a pre-season plan. Another possible risk factor of injuries in this population is the considerable number of students practicing more than 1 sport modality (27%). These multi-sports athletes presented a higher injury rate (10.69 per 1000 A-E, 95%CI = 8.22-13.17) than students practicing a single modality (4.49 per 1000 A-E, 95%CI = 3.51-5.47). The frequency of practices and games was strongly associated with physical activity-related injuries in a study with more than four thousand university students.8 Moreover, it is well known that insufficient sleep time, less than six hours per day, is associated with fatigue injuries,9 a very common concern among medical students.

In contrast with NCAA, a high prevalence of non-contact injuries was found. This was the main mechanism of practice injuries (53%) and the second most common of game injuries (36%). Non-contact injuries represented just 36% and 17% of practices and game injuries in the NCAA, respectively (10). Medical students also had a high incidence of ACL tear (0.39 per 1000 A-E, 95%CI = 0.14-0.63) compared with NCAA (0.15 per 1000 A-E, 95%CI = 0.14-0.15).10 The high incidence of non-contact injuries may reflect poor physical conditioning of medical students, reinforced by the fact that neuromuscular training programs decrease non-contact injuries such as ACL tear.11 Regarding body part injuries, lower limbs represented most of practice and games injuries. Following previous literature,12 the ankle was the most common location of injury (26%), followed by the knee (15%). However, considering severe injuries, the knee was the most affected (26%), followed by the leg and the ankle (21%). The well-established preventive programs to reduce lower limbs injuries are a potential alternative to improve sports safety among medical students.13

CONCLUSION
Junior medical students presented a higher injury rate than seniors. Medical students practicing more than one modality had a higher injury rate than those involved in just one sport modality. Future preventive programs should focus on lower limb injuries, especially in junior medical students and in those practicing more than one sport modality.

Study limitations
This study may be susceptible to memory bias, meaning that a subject may have reported only the injuries that he was able to remember at the end of the season. Another important limitation
is that participating in a match accounted for 1 A-E regardless of time played, due to the technical limitation on accurately assessing time on court or field. Therefore, the expected injury rate may vary significantly among participants with drastically different amounts of minutes played per match.

ACKNOWLEDGMENTS
We thank the Associação Atlética Acadêmica Oswaldo Cruz (Athletic Department of University of São Paulo Medical School) and Henry Dan Kiyomoto for providing support for this research proposal.

AUTHORS’ CONTRIBUTIONS: Each author contributed individually and significantly to the development of this article. AMA: manuscript drafting, data acquisition, and interpretation, critical review of the study’s intellectual content; IJ: data acquisition and interpretation, critical review of the study’s intellectual content; NABC: data acquisition and interpretation, statistical analysis, critical review of the study’s intellectual content; AP: statistical analysis, critical review of the study’s intellectual content; AJH: critical review of the study’s intellectual content, final review, and approval of the manuscript version; TLF: manuscript drafting, critical review of the study’s intellectual content, final review, and approval of the manuscript version.

REFERENCES
1. Mousa OY, Dhamoon MS, Lander S, Dhamoon AS. The MD blues: under-recognized depression and anxiety in medical trainees. PLoS One. 2016;11(6):e0156554.
2. Carek PJ, Laibstain SE, Carek SM. Exercise for the treatment of depression and anxiety. Int J Psychiatry Med. 2011;41(1):15-28.
3. Yorks DM, Frothingham CA, Schuenke MD. Effects of group fitness classes on stress and quality of life of medical students. J Am Osteopath Assoc. 2017;117(11):e17-25.
4. Verhagen E, Collard D, Paw MCA, van Mechelen W. A prospective cohort study on physical activity and sports-related injuries in 10-12-year-old children. Br J Sports Med. 2009;43(13):1031-5.
5. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries: a review of concepts. Sports Med. 1992;14(2):82-99.
6. Dick R, Agel J, Marshall SW. National Collegiate Athletic Association Injury Surveillance System Commentaries: introduction and methods. J Athl Train. 2007;42(2):173-82.
7. Asperti AM, Fernandes TL, Marinho IM, Pedrinelli A, Hernandez AJ. Sports injuries among amateur athletes at a Brazilian university. Acta Ortop Bras. 2017;25(2):93-8.
8. Gao Y, Cai W, Gao L, Wang J, Liang J, Kwok H, et al. Physical activity-related injuries among university students: a multicentre cross-sectional study in China. BMJ Open. 2018;8(9):e021845.
9. Luke A, Lazaro RM, Bergeron MF, Keyser L, Benjamin H, Brenner J, et al. Sports-related injuries in youth athletes: is overscheduling a risk factor? Clin J Sport Med. 2011;21(4):307-14.
10. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. J Athl Train. 2007;42(2):311-9.
11. Gilchrist J, Mandelbaum BR, Melancon H, Ryan GW, Silvers HJ, Griffin LY, et al. A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players. Am J Sports Med. 2008;36(8):1476-83.
12. Roos KG, Kerr ZY, Mauntel TC, Djoko A, Dompier TP, Wikstrom EA. The epidemiology of lateral ligament complex ankle sprains in national collegiate athletic association sports. Am J Sports Med. 2017;45(1):201-9.
13. Brunner R, Friesenbichler B, Casartelli NC, Bizzini M, Mattiuletti NA, Niedermann K. Effectiveness of multicomponent lower extremity injury prevention programmes in team-sport athletes: an umbrella review. Br J Sports Med. 2019;53:282-8.
APPENDIX I
2017 EXPOSURE REPORT

EXPOSURE DEFINITION: One athlete participating in one practice or competition where he or she is exposed to the possibility of an athlete injury (athlete-exposure, A-E). Game participants must have actual playing time.

1. Sport:
   (1) men’s soccer  (2) rugby  (3) men’s volleyball  (4) women’s volleyball  (5) men’s handball  (6) women’s handball  (7) men’s indoor soccer  (8) women’s indoor soccer  (9) men’s basketball  (10) women’s basketball

2. Week: ............

3a. Number of practices this week: .......................

3b. Average number of participants per practice: .................

4a. Number of games this week: .........................

4b. Number of participants with actual playing time:
   Game 1: ...... ...
   Game 2: ...........
   Game 3: ...........
   Game 4: ...........
   Game 5: ...........

Additional comments (optional):

This questionnaire is a version of Injury Surveillance System from NCAA (Dick, R., Agel, J., and Marshall, S.W. (2007). National collegiate athletic association injury surveillance system commentaries: Introduction and methods. Journal of Athletic Training 42, 173-182.)

With permission of Brian Hainline, MD
NCAA Chief Medical Officer
APPENDIX II
2017 INJURY QUESTIONNAIRE

INJURY DEFINITION: A reportable injury is defined as one that:
1. Occurs as a result of participation in an organized university practice or contest; and 2. Injury resulted in restriction of the
student-athlete’s participation or performance regardless of time loss.

1. Name: .............................................................
2. Phone number: ..............................
3. Medical School Year (1st – 6th): .........
4. Gender: (1) male  (2) female
5. Height: ..............................
6. Weight: ..............................
7. Sports practiced: (1) soccer (2) rugby (3) volleyball (4) handball (5) indoor soccer (6) basketball
8. Playing position: ..............................................
9. Dominant body side: (1) right (2) left

INJURY No.1
1. Sport of injury no.1: ..............................................

2. Month of injury no.1:
(1) jan (2) feb (3) mar (4) apr (5) may (6) jun (7) jul (8) aug (9) sep (10) oct (11) nov (12) dec

3. Injury no.1 occurred during:
(1) Preseason (before first regular-season match)  (2) Regular season
(3) Postseason (after final regular-season match)
(99) other: ..............................

4. Injury no.1 occurred in:
(1) Practice  (2) Game

5. Injury no.1 occurred during:
(1) game or practice first half  (2) game or practice second half

6. This injury no.1 is a:
(1) New injury  (2) Recurrence of injury from this season
(3) Recurrence of injury from previous season (this sport)  (4) Complication of previous injury (this sport)
(5) Recurrence of other-sport injury  (6) Recurrence of non-sport injury
(7) Complication of other-sport injury

7. Main body part injured in injury no.1:
(1) head  (2) face  (3) teeth  (4) neck  (5) upper back
(6) ribs  (7) sternum  (8) lower back  (9) abdomen
(10) shoulder  (11) clavicle  (12) scapula  (13) upper arm
(14) forearm  (15) elbow  (16) wrist  (17) hand
(18) finger(s)  (19) pelvis or hips  (20) groin
(21) buttocks  (22) upper leg  (23) knee
(24) lower leg  (25) ankle  (26) foot  (27) toe
(28) stomach  (29) spleen  (30) kidney
(31) external genitalia  (32) coccyx  (33) breast
(34) other: ..............................
8. Body side injured:
   (1) right               (2) left

9. Knee injury:
   (1) collateral ligament  (5) patella and or patella tendon
   (2) anterior cruciate ligament  (6) other tendon
   (3) posterior cruciate ligament  (99) other: ....................
   (4) torn cartilage (meniscus)

10. This injury involved:
   (1) contact with another competitor  (5) no apparent contact (rotation on planted foot)
   (2) no apparent contact (other)  (6) contact with playing surface
   (3) contact with apparatus/ball  (99) other: ....................
   (4) contact with other in environment (e.g., wall, fence, spectators)

11. Primary type of injury no.1:
   (1) contusion  (11) AC separation  (21) nerve injury
   (2) laceration  (12) dislocation (partial)  (22) blisters
   (3) bursitis  (13) dislocation (complete)  (23) hernia
   (4) tendinitis  (14) fracture  (24) foreign object in body orifice
   (5) ligament sprain (incomplete tear)  (15) stress fracture  (25) internal injury (non-hemorrhage)
   (6) ligament sprain (complete tear)  (16) concussion  (26) infection
   (7) muscle-tendon strain (incomplete tear)  (17) heatstroke  (27) periostitis
   (8) muscle-tendon strain (complete tear)  (18) hemorrhage  (28) inguinal hernia
   (9) osseous edema  (19) infection  (99) other: ....................
   (10) torn cartilage  (20) avulsion (tooth)

12. Did this injury require surgery?
   (1) Yes, in-season  (2) Yes, postseason  (3) No

13. Describe the joint surgery?
   (1) Arthroscopy  (4) no joint surgery:
   (2) Diagnostic arthroscopy  (99) other: ....................
   (3) Operative arthroscopy

14. Injury assessment (best assessment procedure):
   (1) clinical exam by athletic trainer  (5) other image technique
   (2) clinical exam by physician  (6) surgery
   (3) X-ray  (7) blood work lab test
   (4) MRI  (99) other: ....................

15. Days lost from sport activity: ..................................................

Additional comments (optional):

This questionnaire is a version of Injury Surveillance System from NCAA (Dick, R., Agel, J., and Marshall, S.W. (2007). National collegiate athletic association injury surveillance system commentaries: Introduction and methods. Journal of Athletic Training 42, 173-182.)

With permission of Brian Hainline, MD
NCAA Chief Medical Officer