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# ANALYSIS OF HIGH-INTENSITY EFFORTS IN BRAZILIAN PROFESSIONAL SOCCER PLAYERS

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ABSTRACT
**Purpose.** The study aim was to characterize high-intensity efforts (HIEs) of soccer players.
**Methods.** The HIE features were quantified according to playing positions, with the consideration of the moment of initial velocity increase, which precedes the velocity threshold. The total of 107 players of Brazilian first division championship were analysed with the automatic tracking method. HIE phase 1 began at the minimum local value and finished when the velocity reached 6.4 m/s. Phase 2 began immediately when the velocity exceeded 6.4 m/s and finished with the velocity lower than 6.4 m/s.
**Results.** External defenders and forwards performed a greater ($p < 0.01$; *d:* 1.01–1.17) number of HIEs (40.0 ± 13.5 and 34.9 ± 6.6, respectively) than central defenders (26.6 ± 9.2). With respect to the distance covered and duration of phase 2, external defenders covered a greater ($p < 0.01$; *d:* 0.45–0.47) distance (13.5 ± 4.5 m) and spent more ($p < 0.01$; *d:* 0.24–0.26) time (1.8 ± 1.3 s) than central defenders (11.5 ± 4.3 m; 1.5 ± 1.2 s), forwards (11.4 ± 4.4 m; 1.5 ± 0.9 s), central midfielders (11.5 ± 4.4 m; 1.5 ± 1.2 s), and external midfielders (11.4 ± 4.6 m; 1.5 ± 1.1 s). Players performed a greater ($p = 0.03$; *d:* 2.29–5.17) number of HIEs with more than 120 s of recovery time compared with other time categories.
**Conclusions.** The better characterization of HIE physical demands during soccer matches provides insights for coaches to plan a more specific physical training for professional players.
**Key words:** automatic tracking, match analysis, physical demands, sprint

## INTRODUCTION

Soccer is characterized as an intermittent exercise because it involves alternating between walking, jogging, and running at low, medium, and high intensities [1–4]. Some special attention has been paid in recent studies [5–10] to the players' high-intensity efforts (HIEs) because they are highly associated with important moments in the match and with the most frequent actions in goal situations [7, 11]. Although literature findings show that high-intensity running represents the range of 4–10% of the total distance covered in a match [1, 6, 12, 13], the analysis of these HIEs is also important for evaluating physical training specific to the modality [3].

Part of HIE analysis has been performed with the quantification of the player's total distance covered in sprinting situations. Some authors have reported a decrease in the distance covered at greater velocities from the first half to the second half [6, 8], commonly associated with a decline of the physical performance.

The decrease in performance between the first and second halves can also be evaluated by the recovery time taken by players between consecutive intense actions [6]. According to Stolen et al. [14], players need a period of low intensity activities for lactate re-

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moval and recovery of lost energy substrates after periods with HIEs during matches. The ability to recover and reproduce performance in subsequent sprints, termed repeated-sprint ability (RSA), is believed to be a specific fitness requirement of soccer and other team sports athletes [15, 16].

Despite the relevance of the data presented in literature concerning soccer players' HIEs, there are some methodological considerations that deserve to be discussed for a characterization of the activities of a player during a game. A given player performs an HIE when a velocity threshold is reached. However, according to Carling et al. [13], there is no agreement on what velocity thresholds should be used in soccer to state that the player is sprinting. For example, thresholds have been reported at velocities of > 8.33 m/s [3], > 7 m/s [10], > 6.39 m/s [1, 2], and > 5.83 m/s [9]. There is also a proposal to use an individualized velocity threshold for each athlete [16]. On the other hand, Di Salvo et al. [10] suggested analysing sprint activities in a more specific way, classifying them as 'explosive' and 'leading' sprint. The authors assessed separately the sprints in which, before reaching the threshold, the athletes were in low velocities (labelled 'explosive sprint') or in moderate velocities ('leading sprint'). This proposal demonstrates the relevance of the players' initial velocity but this information is usually discarded. Consequently, important data about the player's effort is ruled out as well. In other words, to characterize the HIEs of an athlete, it is valuable to quantify data about the physical performance not only from the moment in which the player reaches the velocity threshold but also from the one he begins to increase the velocity.

Therefore, the purpose of the present study was to quantify and characterize the HIEs of Brazilian soccer players. Specifically, the players' HIE features were quantified according to their playing positions, with the consideration of the moment of initial increase of the velocity, which precedes the velocity threshold. The initial hypothesis was that the HIE features were dependent on the player's role on the field, so different effort demands would be found among the playing positions.

## METHODS

### Data collection

Nine Brazilian first division championship 2003–2008 matches were recorded with four digital cameras (30 Hz). The cameras were positioned at the highest points of the stadiums, each covering roughly a quarter of the field. The temperatures ranged from 20°C to 30°C and the score difference ranged from 0 to 2 goals for eight matches; only 1 match presented a score difference of 3 goals. The total of 5 players were dismissed and the substitutions ranged from 4 to 6 in each match. All dismissals and substitutions took place late in the second half.

### Subjects

The Ethics Committee of the Paulista State University approved the research. The total of 107 players, of 18 different teams, who played the entire game were analysed. Players involved in substitutions or dismissals were excluded from the analysis, as well as goalkeepers. The athletes were classified according to the five playing positions on the field: central defenders (CD, $n$ = 27), external defenders (ED, $n$ = 25), central midfielders (CM, $n$ = 18), external midfielders (EM, $n$ = 17), and forwards (F, $n$ = 20).

### Automatic tracking method

After the games, the video images were transferred to computers for analysis. Players' trajectories were obtained with the use of the DVideo software interface [17, 18]. The DVideo software has the automatic tracking rate of 94% of the processed frames, the average error of 0.3 m for the determination of player position, and the average error of 1.4% for the distance.

### Data processing

The 2D players' trajectories were smoothed by a third-order Butterworth low-pass filter with the cut-off frequency of 0.4 Hz, defined as described in a previous study [19]. The distances covered by each player were calculated as the cumulative sum of player displacement between two successive samplings. The velocity curves were obtained by means of numerical derivation.

In order to determine the initial increase of the velocity, we detected all the local minimum and local maximum points of the velocity curves of each player. We identified the local maximum that exceeded the velocity of 6.4 m/s (peak velocity) and the local minimum prior to it, which represents the HIE initial velocity. The velocity of 6.4 m/s was defined in accordance with literature studies [1, 2], and represents the velocity above the anaerobic threshold of professional soccer players [6].

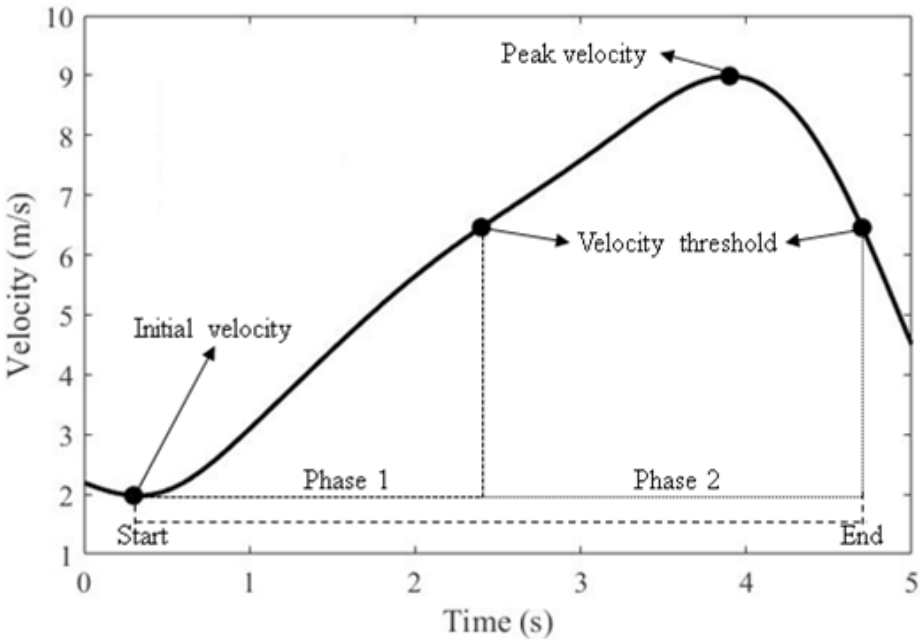


Figure 1. Example of a high-intensity effort performed by a player during a soccer match

With this detection, we characterized each HIE performed. The HIEs were divided into two phases. Phase 1 began at the minimum local value and finished where the velocity reached 6.4 m/s. Phase 2 began at the moment in which the velocity exceeded 6.4 m/s and finished immediately when the velocity became lower than 6.4 m/s (Figure 1).

We detected 3958 HIEs performed by the players during the nine matches analysed. Then, the following variables were calculated: (a) total HIEs performed; (b) distance covered for phase 1, phase 2, and total (both phases combined); (c) effort duration for phase 1, phase 2, and total; (d) initial velocity; (e) peak velocity; (f) time between the HIEs; (g) time walking after HIE. The last one represents the features of the physical activity during recovery periods and was calculated as the percentage of time that the player spent below 1.4 m/s in the following 60 s after the end of each HIE. This velocity was defined in accordance with Mohr et al. [3] and Buchheit et al. [15].

In addition, for better characterization of the recovery time, the number of HIEs performed by the players was grouped into five different categories of recovery time (0–9, 10–30, 30–60, 60–120, and > 120 s), in accordance with Vigne et al. [6].

## Statistical analysis

All data are presented as means ± standard deviations. First, the normality of the data distribution was tested by the Lilliefors test. The comparisons were performed with the one-way analysis of variance (ANOVA) when normality was confirmed; otherwise, the Kruskal-Wallis non-parametric test was used. The HIE variables (total HIEs performed, distance covered phase 1, distance covered phase 2, total distance covered, effort duration phase 1, effort duration phase 2, total effort duration, initial velocity, peak velocity, time between the HIEs, and time walking after HIE) were compared between the playing positions (CD, ED, CM, EM, F). The 5 different categories of recovery time (0–9, 10–30, 30–60, 60–120, > 120) were also compared, with the consideration of the playing positions (CD, ED, CM, EM, F). When differences were found, Tukey's post-hoc test was applied. Statistical significance was set at $p < 0.05$. The effect sizes were calculated and classified as small ($d > 0.20$), medium ($d > 0.50$), and large ($d > 0.80$), as previously proposed by Cohen [20]. All statistical procedures were performed with the MATLAB software (MathWorks Inc., Natick, MA, USA).

## Ethical approval

The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

**Table 1.** Mean (± standard deviation) of total HIEs performed, distance covered, effort duration, initial velocity, peak velocity, time between the HIEs, and time walking after an HIE relative to playing positions and the total

| Variables | CD | ED | CM | EM | F | Total | Tukey's post-hoc test |
|---|---|---|---|---|---|---|---|
| Total HIE performed | 26.6 (± 9.2) | 40.0 (± 13.5) | 27.6 (± 8.1) | 34.2 (± 14.8) | 34.9 (± 6.6) | 32.4 (± 11.8) | ED > CD, CM; F > CD |
| Distance covered, phase 1 (m) | 8.0 (± 4.3) | 8.5 (± 4.5) | 8.3 (± 4.4) | 8.4 (± 4.6) | 8.3 (± 4.4) | 8.3 (± 4.5) | CD; ED; CM; EM; F |
| Distance covered, phase 2 (m) | 11.5 (± 4.3) | 13.5 (± 4.5) | 11.5 (± 4.4) | 11.4 (± 4.6) | 11.4 (± 4.4) | 12.0 (± 9.1) | ED > CD, CM, EM, F |
| Total distance covered (m) | 19.5 (± 9.8) | 22.0 (± 11.3) | 19.8 (± 10.5) | 19.8 (± 9.6) | 19.7 (± 8.3) | 20.3 (± 10.2) | ED > CD, CM, EM, F |
| Effort duration, phase 1 (s) | 2.2 (± 1.4) | 2.2 (± 1.4) | 2.2 (± 1.4) | 2.2 (± 1.4) | 2.2 (± 1.4) | 2.2 (± 1.4) | CD; ED; CM; EM; F |
| Effort duration, phase 2 (s) | 1.5 (± 1.2) | 1.8 (± 1.3) | 1.5 (± 1.2) | 1.5 (± 1.1) | 1.5 (± 0.9) | 1.6 (± 1.2) | ED > CD, CM, EM, F |
| Total effort duration (s) | 3.7 (± 2.3) | 4.0 (± 2.7) | 3.7 (± 2.5) | 3.7 (± 2.2) | 3.7 (± 1.8) | 3.8 (± 1.8) | ED > CD, CM, EM, F |
| Initial velocity (m/s) | 2.1 (± 1.8) | 2.2 (± 1.9) | 2.3 (± 1.8) | 2.4 (± 1.8) | 2.3 (± 1.8) | 2.2 (± 1.8) | CD; ED; CM; EM; F |
| Peak velocity (m/s) | 7.2 (± 0.7) | 7.3 (± 0.8) | 7.2 (± 0.7) | 7.2 (± 0.6) | 7.3 (± 0.7) | 7.2 (± 0.7) | CD; ED; CM; EM; F |
| Time between the HIEs (s) | 193.2 (± 216.5) | 130.0 (± 140.5) | 181.6 (± 199.5) | 148.1 (± 159.5) | 129.8 (± 120.1) | 157.9 (± 176.8) | CD, CM > ED, EM, F |
| Time walking after HIE (%) | 47.6 (± 16.6) | 42.0 (± 16.5) | 40.8 (± 16.6) | 41.5 (± 18.3) | 47.0 (± 18.1) | 44.3 (± 17.3) | CD, F > ED, CM, EM |

HIE – high-intensity effort
CD – central defenders
ED – external defenders
CM – central midfielders
EM – external midfielders
F – forwards

**Table 2.** Mean (± standard deviation) of the HIEs performed with different recovery times relative to playing positions and as totals

| | Average number of HIEs | | | | | | |
|---|---|---|---|---|---|---|---|
| Time between the HIEs | CD | ED | CM | EM | F | Total | Tukey's post-hoc test |
| 0–9 s | 3.7 (± 2.2) | 6.7 (± 4.8) | 3.3 (± 2.5) | 5.3 (± 4.0) | 4.8 (± 2.0) | 4.8 (± 3.4) | ED > CD, CM |
| 10–30 s | 1.3 (± 1.3) | 3.1 (± 2.2) | 2.5 (± 2.1) | 3.1 (± 3.1) | 2.8 (± 1.4) | 2.4 (± 2.1) | ED, F > CD |
| 30–60 s | 2.6 (± 2.5) | 5.0 (± 3.4) | 2.1 (± 1.4) | 3.9 (± 4.4) | 3.9 (± 2.7) | 3.8 (± 3.1) | ED > CD, CM |
| 60–120 s | 4.8 (± 3.2) | 9.3 (± 5.7) | 5.1 (± 2.4) | 6.8 (± 3.6) | 8.2 (± 2.6) | 6.8 (± 4.2) | ED, F > CD, CM |
| > 120 s | 14.1 (± 3.1) | 15.9 (± 2.6) | 14.5 (± 2.7) | 15.1 (± 2.6) | 15.2 (± 2.2) | 14.9 (± 2.7)* | CD; ED; CM; EM; F |

HIE – high-intensity effort
CD – central defenders
ED – external defenders
CM – central midfielders
EM – external midfielders
F – forwards

* significantly different than for 0–9, 10–30, 30–60, and 60–120 s

## RESULTS

The results of all HIE variables are presented relative to the playing positions and as totals in Table 1. Significant differences among the playing positions were found for the total HIE performed: external defenders performed more HIEs than central defenders and central midfielders ($p < 0.01$; $d$: 1.07–1.17). Moreover, forwards performed more HIEs than central defenders ($p < 0.01$; $d = 1.01$). No differences were observed between forwards and external defenders, as well as between central defenders and central midfielders. There was no significant difference between the playing positions for the distance covered during phase 1 of each HIE ($p = 0.30$). However, when considering the distance covered in phase 2, external defenders presented a significantly higher value compared with all other playing positions ($p < 0.01$; $d$: 0.45–0.47). When the two phases were analysed together, external defenders covered greater distances than the other players ($p < 0.01$; $d$: 0.21–0.24). The duration of each HIE in phase 1 showed no significant differences among the playing positions ($p = 0.70$). However, during phase 2 and for both phases, external defenders presented a significantly longer HIE compared with the other players ($p < 0.01$; $d$: 0.24–0.26 and $p < 0.01$; $d$: 0.12–0.13, respectively). No significant differences were noted among the playing positions for the initial ($p = 0.08$) and peak velocity ($p = 0.05$). Additionally, as depicted in Table 1, the average time between the HIEs of central defenders and central midfielders was significantly longer than in the external defenders ($p < 0.01$; $d$: 0.31–0.34), external midfielders ($p < 0.01$; $d$: 0.01–0.05), and forwards ($p < 0.01$; $d$: 0.32–0.35). Moreover, central defenders and forwards spent significantly more time walking after an HIE than external defenders ($p < 0.01$; $d$: 0.29–0.34), central midfielders ($p < 0.01$; $d$: 0.36–0.41), and external midfielders ($p < 0.01$; $d$: 0.30–0.35).

Table 2 presents the results of the HIEs performed in different categories of recovery time relative to the playing positions and as totals. The players performed a greater number of HIEs with a recovery time > 120 s compared with other categories of recovery time ($p < 0.03$; $d$: 2.29–5.17). External defenders presented significantly more HIEs with 0–9 s recovery time than central defenders or central midfielders ($p = 0.01$; $d$: 0.81–0.85). As for the recovery time of 10–30 s, external defenders and forwards performed more HIEs than central defenders ($p < 0.01$; $d$: 1.01–1.12). External defenders also performed a greater number of HIEs with the recovery time of 30–60 s than central defenders or central midfielders ($p < 0.01$; $d$: 0.81–1.05). Finally, external defenders and forwards performed more HIEs with the recovery time of 60–120 s than central defenders or central midfielders ($p < 0.01$; $d$: 0.91–1.24). As for the recovery time between HIEs > 120 s, there were no significant differences between the playing positions ($p = 0.15$).

## DISCUSSION

The purpose of the present study was to analyse the HIEs performed by Brazilian soccer players during official soccer matches. Specifically, we quantified the HIE features according to playing positions. Furthermore, we adopted a new analysis pattern that took into consideration the moment of the initial velocity increase, which precedes the velocity threshold. The results revealed differences among the playing positions in the total HIEs performed, distance covered (phase 2 and total), effort duration (phase 2 and total), time between the HIEs, and time walking after HIE. Therefore, the initial hypothesis that the effort demands are different depending on the playing position was confirmed. In addition, it is also possible to visualize that during phase 1 of an HIE, players covered a shorter distance when compared with phase 2. However, the duration of phase 1 was greater (Table 1).

The study proved that 60 s after an HIE, the players walked 44% of the time on average. Within this period, players can recover more than 80% of phosphocreatine reserves and the intramuscular concentration of pH [5, 21]. Thus, the period that players spend walking has been associated with the players' need for recovery. Once sprint movements require great energy consumption, players need to remain in low-intensity activities for lactate removal and the recovery of lost energy substrates after periods of high-intensity activities during matches [14, 22]. However, it is important to highlight that the dynamics of soccer may not require players to perform HIEs sequentially in a short period of time. Therefore, future investigations should analyse the technical and tactical causes for HIE action and the way these data are associated with physiological responses.

As for the time between the HIEs, the results showed that players took an average of 158 s to perform another HIE. However, the standard deviation was greater than the mean value (176 s), revealing great variability. For this reason, we decided to classify the number of HIEs into different categories of recovery time. The

results indicate that 66% of HIEs are performed with a time between them greater than 60 s. This finding does not corroborate with the values reported by Vigne et al. [6], who observed intervals of 2–60 s between consecutive high-intensity running in approximately 85% of the time. Bradley et al. [23] also found lower values than those in the present study, ranging from 39 to 70 s, depending on the playing position. These differences may occur because the sprint value threshold assumed by Bradley et al. [23] and Vigne et al. [6] was 5.28 m/s, a value below the one defined in the present study (6.4 m/s). Therefore, with a lower threshold value, it is possible that players are more frequently at high-intensity running and, consequently, it is expected that the time between the sprints decreases. However, the recovery time between the HIEs found in the present study turned out lower than that reported by Ade et al. [9], although they defined a lower velocity threshold (5.83 m/s). This difference can be related to the characteristics of HIEs because the values of duration and the distance covered per sprint are greater for all playing positions when compared with our results (i.e., phase 2). However, the number of HIEs performed is greater in the present study (except for midfielders). Thus, the players analysed by Ade et al. [9] performed less numerous but more intense HIEs and needed more recovery time between them. In this way, the differences between our findings and the results of the referred studies [6, 9, 23] can also be associated with the characteristics of different leagues or nationalities [24, 25]. Literature [6, 9] and our findings reveal the existence of HIEs in a sequence with a short time between them, suggesting that players perform HIEs without being fully recovered. Some authors [15, 22, 26, 27] have concluded that the ability to recover and perform another HIE in a sequence is equivalent to the RSA. Performing sequences of HIEs is a skill required in soccer and other team sports [15].

The characterization of the players' HIEs with the initial velocity (2.2 ± 1.8 m/s) demonstrated that the athletes did not perform their sprints from the steady position. This quantification is extremely important to a better understanding of players' physical actions during a match. Furthermore, the majority of the existing tests to evaluate the physical capacity of soccer players, such as the Yo-Yo [28] and Running Anaerobic Sprint Test [29], allow a short period of active recovery but require players to start in the steady position.

Another feature that should be discussed is the recovery time between efforts, once the recoveries in the evaluation tests range from 10 to 25 s [28, 29]. Players performed the average of only 2.4 HIEs during a game with the recovery time 10–30 s. However, they did not perform them consecutively as tests assess them. In the tests, players are evaluated during consecutive efforts with equally long recoveries. In this way, the tests may not reflect what occurs in matches, as reported by Aquino et al. [30]. Thus, our findings promote information that can be used for adjustments in the requirements of the physical tests, and help researchers to evaluate players' performance in conditions similar to real match situations.

In relation to playing positions, the present study revealed that central defenders and central midfielders performed fewer HIEs and, consequently, their time between efforts was greater when compared with external defenders, external midfielders, and forwards. Ade et al. [9], Di Salvo et al. [2, 7], and Bradley et al. [8] also observed that central defenders performed fewer HIEs and presented a greater time period between them. However, Bradley et al. [8] identified that external midfielders and central midfielders were characterized by lower values of recovery time between HIEs, compared with the other playing positions. When comparing the peak velocity reached in an HIE between playing positions, Bradley et al. [8] also observed that external defenders, external midfielders, and forwards reached higher velocities than central defenders or central midfielders. However, in the present study, no differences were found among the playing positions. The divergence among the studies may be explained by the individual characteristics of different leagues or nationalities [24, 25].

Analysing the HIE phase 2, we found that external defenders covered greater distances with longer durations of each HIE compared with the other players. Furthermore, the time between the HIEs across the different categories indicates that external defenders perform more HIEs with 10–120 s between them compared with central defenders and central midfielders. Vigne et al. [6] also reported that external midfielders performed more HIEs with the recovery time of 10–60 s than central defenders. Differences were also observed among playing positions in the percentage of time that the players walked after an HIE. Forwards and central defenders walked for longer periods after an HIE than external defenders, central midfielders, or external midfielders. This result may indicate that forwards and central defenders need more time to recover compared with other players. However, these differences may also be a consequence of the tactical role of the playing positions within the team. The re-

sults presented point at a characteristic of this playing position that differentiates it from the other playing positions and provides a valuable insight for coaches.

Finally, the characterization of HIEs with reference to the playing positions proves that external defenders perform a greater number of HIEs, present longer distances and durations of each HIE, perform numerous HIEs with short recovery times, and spend less time walking after an HIE compared with the other players. Therefore, these findings provide coaches with better conditions to train and evaluate soccer players according to their individual requirements during official matches.

## CONCLUSIONS

The paper presented a detailed report on the HIEs performed by soccer players during official matches. We demonstrated that the HIEs differed depending on the playing position. The result concerning the initial velocity revealed that the players did not perform HIEs starting with the steady position. The findings promote a better characterization of the physical demands of HIEs during soccer matches, providing insights for coaches in order to plan a more specific physical training for professional players.

### Disclosure statement

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### Conflict of interest

Authors state no conflict of interest.

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