

# Effect of player substitutions on the intensity of second-half soccer match play

## *O efeito das substituições realizadas no segundo tempo da partida na intensidade de jogo de futebol*

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**Abstract** – Most soccer matches are conducted by coaches who usually make all player substitutions allowed. Therefore, it is extremely important to study these substitutions and their effects on the intensity of effort required from players. To date, no published studies have reported on this topic using heart rate (HR) as an intensity parameter. The objective of this study was to compare effort intensity (EI) of soccer players in the following situations: 1) first half (FH-EI); 2) second half (SH-EI); 3) second half with substitutions (SHS-EI). Forty-five male soccer players (18.5±1.2 years old, 74.25±5.79 kg, 182.6±8.55 cm, 9.56±2.47% body fat, 56.3±4.3 mL O<sub>2</sub>/kg/min) were evaluated during 29 official games. EI was considered as the mean HR, expressed as the percentage of each player's maximal HR (%HR<sub>max</sub>) and as the time spent in each intensity zone (Z) according to %HR<sub>max</sub> (Z1<70%; Z2 70-85%; Z3 85-90%; Z4 90-95%; Z5 95-100%). FH-EI (86.3±3.3%HR<sub>max</sub>) was higher than SH-EI (80.6±4.4%HR<sub>max</sub>) and SHS-EI (83.6±2.8%HR<sub>max</sub>). SHS-EI was higher than SH-EI (p<0.05). Time spent in high-intensity zones was lower in SH-EI than in FH-EI, but higher in SHS-EI when compared to SH-EI (p<0.05). It was concluded that the decrease in EI in the second half of soccer matches was attenuated by substitutions made at halftime, as evidenced by a longer time spent in high-intensity zones when compared to SH-EI.

**Key words:** Heart rate; Soccer; Sports.

**Resumo** – A maioria das partidas de futebol é conduzida por treinadores que realizam todas as substituições de jogadores permitidas. Dessa maneira, torna-se de extrema importância o estudo destas substituições e sua influência na intensidade de esforço dos atletas. Há de se mencionar, ainda, que não há nenhum estudo na literatura que tenha investigado sobre esse tópico utilizando a frequência cardíaca (FC) como um parâmetro de intensidade. O objetivo deste estudo foi comparar a intensidade de esforço (IE) dos jogadores de futebol nas situações: 1) primeiro tempo (PT-IE); 2) segundo tempo (ST-IE); 3) segundo tempo com substituições (STS-IE). Quarenta e cinco atletas de futebol do sexo masculino (18.5 ± 1.2 anos, 74.25 ± 5.79 kg, 182.6 ± 8.55 cm, 9.56 ± 2.47 %G, 56.3 ± 4.3 mL O<sub>2</sub>/kg/min) participaram do estudo durante 29 jogos oficiais. IE foi considerada como a média da FC, expressa em percentual da FC máxima (%FC<sub>max</sub>) de cada atleta e também de acordo com o tempo percorrido em cada zona de intensidade (Z) específica de acordo com o %FC<sub>max</sub> (Z1<70%; Z2 70-85%; Z3 85-90%; Z4 90-95%; Z5 95-100%). IE no PT-IE (86.3 ± 3.3%FC<sub>max</sub>) foi maior que no ST-IE (80.6 ± 4.4%FC<sub>max</sub>) e que no STS-IE (83.6 ± 2.8 %FC<sub>max</sub>). IE no STS-IE foi maior que no ST-IE (p<0,05). O tempo percorrido nas zonas de alta intensidade foi menor no ST-IE quando comparado com o PT-IE e maior no STS-IE quando comparado com o ST-IE (p<0,05). Conclui-se que a diminuição da IE no segundo tempo da partida de futebol foi atenuada com a realização de substituições e foi evidenciado um maior tempo de permanência em zonas de alta intensidade quando comparado com o ST-IE.

**Palavras-chave:** Esportes; Frequência cardíaca; Futebol.

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## INTRODUCTION

The work load imposed on soccer players during an official match has been described by several variables, such as distance covered<sup>1</sup>, average running speed<sup>2</sup>, body temperature<sup>3</sup>, oxygen uptake, blood lactate concentration<sup>4</sup>, mean energy expenditure<sup>5</sup>, and heart rate (HR)<sup>6-10</sup>. Among these variables, the direct measurement of oxygen uptake ( $\text{VO}_2$ ) would provide the optimal standard for assessing the intensity of effort required from players during an official competition. However, such measurement procedures would noticeably interfere with the athlete's performance. Moreover, the use of any electronic equipment by soccer players during official matches is risky and officially not allowed<sup>11</sup>.

Therefore, HR appears to be the most feasible and practical variable to determine effort intensity (EI) and to estimate aerobic energy production in team sports<sup>6,9</sup>, including intermittent exercises such as soccer<sup>12</sup>.

Because HR is influenced by factors such as age, fitness, gender, environmental conditions, and hydration status, Karvonen and Vuorimaa<sup>13</sup> recommend that HR should be determined as a percentage of the maximal HR ( $\text{HR}_{\text{max}}$ ) to be used as a parameter of exercise intensity. Thus, this variable may represent an adequate parameter to control exercise intensity in professional and non-professional soccer players<sup>14</sup>.

A possible way to analyze performance patterns and fatigue development during a soccer match is by comparing EI of soccer players who played only in the second half of a game with their EI when playing both halves<sup>15</sup>. The decrease in mean EI for the whole team may be attenuated if players are replaced with rested players in the second half of the match. Conversely, EI may rise in matches with player dismissals<sup>16</sup>.

It is well known that EI tends to decrease in the second half of a soccer match in relation to its first half<sup>10</sup>. Most studies investigating the physical effort that players exert during a soccer match do not take into account player substitutions made during the games<sup>6,15</sup>. Therefore, the literature on this issue is scarce, and so is information on how substitutions can affect the overall intensity of soccer match play. Considering that most soccer matches are conducted by coaches who usually make all player substitutions allowed, it is extremely important to study the effects of these substitutions on the intensity of effort required from players. Because soccer matches are won by long-duration effort, understanding the overall intensity of match play and its relationship to player substitutions could be a valuable tool for coaches in developing tactical strategies during the games and in making better decisions to improve team performance.

This study aimed to compare EI of soccer players in the second half of a soccer match when substitutions were made with EI when no substitutions were made. We hypothesized that EI would be higher in the second half with substitutions made at halftime.

## METHODS

### Subjects

Forty-five male professional soccer players ( $24 \pm 2.4$  years old,  $74.25 \pm 5.79$  kg,  $182.6 \pm 8.55$  cm,  $9.56 \pm 2.47\%$  body fat,  $56.3 \pm 4.3$  mL $O_2$ /kg/min) of a Brazilian first division soccer team who attended regular training sessions and competed in official events organized by the Brazilian Soccer Confederation (CBF) participated in this study.

The study was approved by the Research Ethics Committee of Universidade Federal de Minas Gerais (protocol no. ETIC 476/04). Written informed consent was obtained from all participants after they were informed about the study objectives, methods, and the possibility to leave the trial at any time without prior justification.

On the first day of experiments, all subjects were weighed and their height and skinfolds were measured to estimate body fat percentage<sup>17</sup>. The maximal oxygen uptake ( $VO_{2max}$ ) was estimated using the field test proposed by Margaria et al.<sup>18</sup>, which consisted of running 2400 m at the highest individual running speed. Running time was used to calculate  $VO_{2max}$ .

### Procedures

HR of all subjects was monitored during 29 official matches (Polar® Team System, Polar® Electro Oy, HQ, FIN-90440, Kempele, Finland). This equipment allows recording HR during an activity without the need for a pulse monitor, with the data being recorded every 5 seconds.

$HR_{max}$  of each subject was determined as the highest HR found in one of these two situations:

- 1) Maximal test to determine  $VO_{2max}$ <sup>18</sup>.
- 2) The highest HR recorded during the matches<sup>19</sup>.

The individual effort was considered as the percentage of  $HR_{max}$ , which was determined as the ratio between the two situations mentioned above. The use of a HR percentage is recommended because absolute values are influenced by external factors<sup>13</sup>. Individual EI, expressed as the percentage of  $HR_{max}$  ( $\%HR_{max}$ ), was calculated by dividing the mean HR of each player during a given match by his own  $HR_{max}$ .

A total of 45 players were monitored during soccer matches. For every match, HR was analyzed over the entire match and also at the first and second halves independently. Forty-five soccer players who played at least one entire match were divided according to their playing position and randomly assigned to HR monitoring in this study. Of these 45 subjects, 15 also played and were monitored only in the second half of other official games. Individual EI was measured in these 15 players when playing only in the second half, and this situation was considered as player substitutions that normally occur in soccer matches. It is important to note that official rules allow up to 3 substitutions during a soccer game, and therefore, less

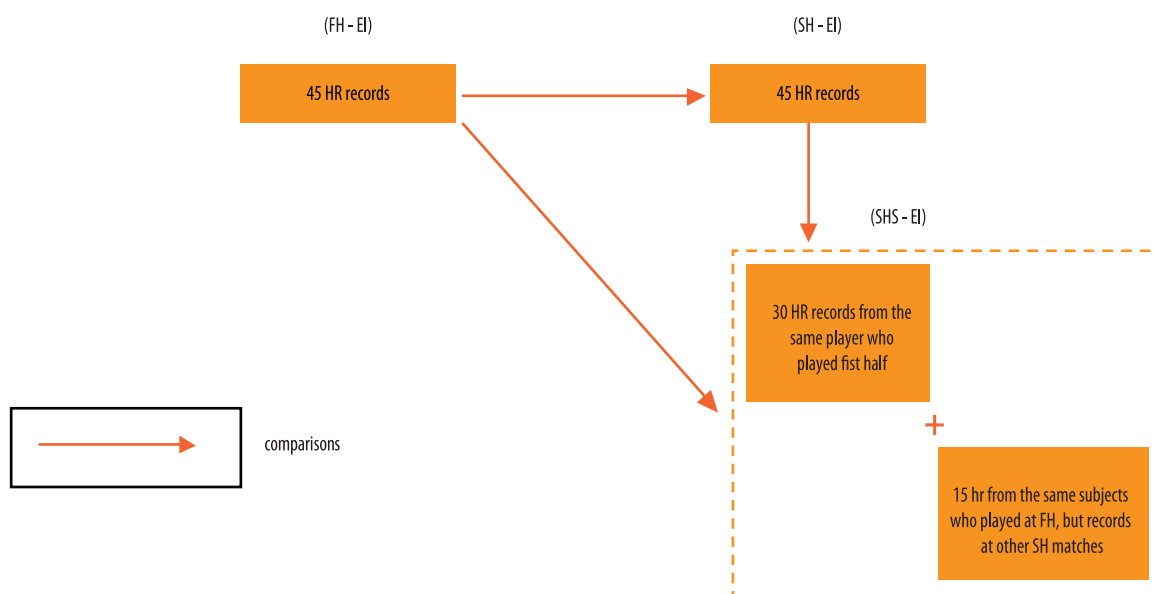
than one third of the players can be replaced. All substitutions were made by replacing players in the same team position (3 forwards [23%], 4 defenders [27%], and 8 midfielders [55%]).

The following EI groups were analyzed and compared (Figure 1):

1) First-half EI (FH-EI): 45 players – EI measured in the first half from participants who played entire matches.

2) Second-half EI (SH-EI): 45 players – EI measured in the second half from the same subjects of the first group, who played entire matches.

3) Second-half EI, including substitutions (SHS-EI): 30 players – EI measured in the first half from soccer players who played an entire match; and 15 players – same subjects who played in the first half, but EI was assessed at other matches when they played only in the second half. Therefore, this group design represents a real-life soccer game, with approximately one third of the players being replaced.



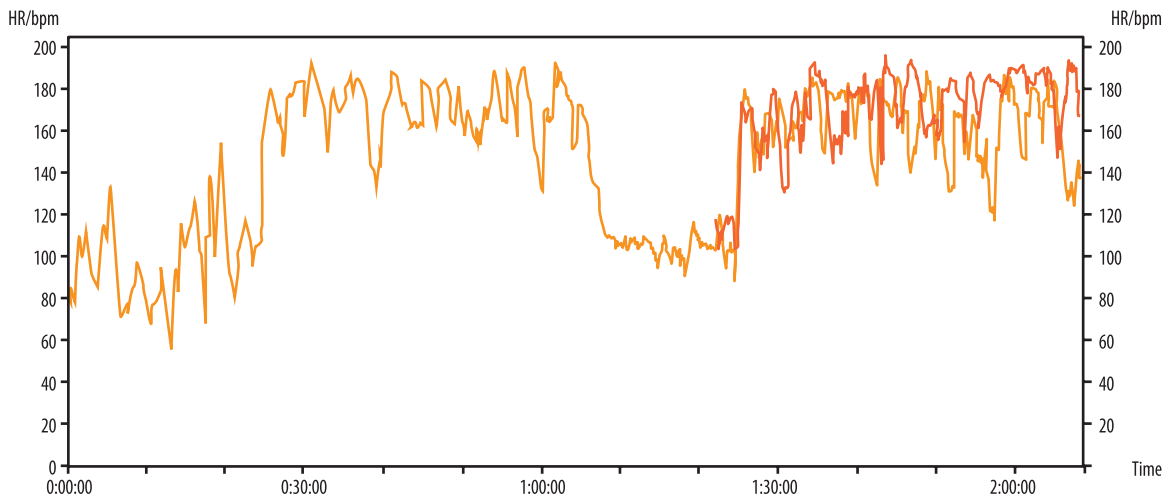
**Figure 1.** Schematic comparison of effort intensity (EI) in experimental groups. EI groups were compared as illustrated above. FH-EI: first-half effort intensity group; SH-EI: second-half effort intensity group; SHS-EI: second-half effort intensity group including substitutions.

Figure 2 shows how HR was analyzed in each soccer player when a substitution was made. The gray HR line on the right side of the figure represents the athlete's HR when he played only in the second half of a match. It should be noted that his HR was higher than the value recorded during the second half in comparison with the player who participated in the entire game.

Throughout the competition, mean drying temperature, humid temperature and relative humidity were  $23.9 \pm 2.7^\circ\text{C}$ ,  $18.9 \pm 2.5^\circ\text{C}$  and  $63.3 \pm 15.9\%$ , respectively. The competition was held between August and November in a Brazilian subtropical region.

EI was also analyzed as the percentage of time spent during the game in five different intensity zones: Zone 1:  $< 70\%HR_{\max}$ ; Zone 2:  $70\text{--}85\%HR_{\max}$ ; Zone 3:

85-90%HR<sub>max</sub>; Zone 4: 90-95%HR<sub>max</sub>; Zone 5: 95-100%HR<sub>max</sub>. The intensity zone division follows that described by Helgerud et al.<sup>8</sup> and was intended to obtain a more detailed analysis of different exercise intensity zones to which players are subjected during official soccer games whether substitutions are made or not.



**Figure 2.** Example of heart rate (HR) monitoring of one soccer player during an official match (thin line) and during the second half of another soccer.

### Statistical analysis

The results are expressed as mean  $\pm$  standard deviation (SD). One-way analysis of variance (ANOVA) was used to compare the situations analyzed (FH-EI, SH-EI, and SHS-EI), and two-way ANOVA to compare intensity zones in each situation. All tests were followed by *post hoc* Tukey's test. The level of significance was set at  $p < 0.05$ .

## RESULTS

Table 1 shows HR<sub>max</sub> results achieved in the aerobic tests and in the matches. It also shows the percentage of players who obtained their HR<sub>max</sub> either in a match or in the field test.

**Table 1.** Maximal heart rate (HR<sub>max</sub>) and percentage distribution of players according to soccer matches and field test

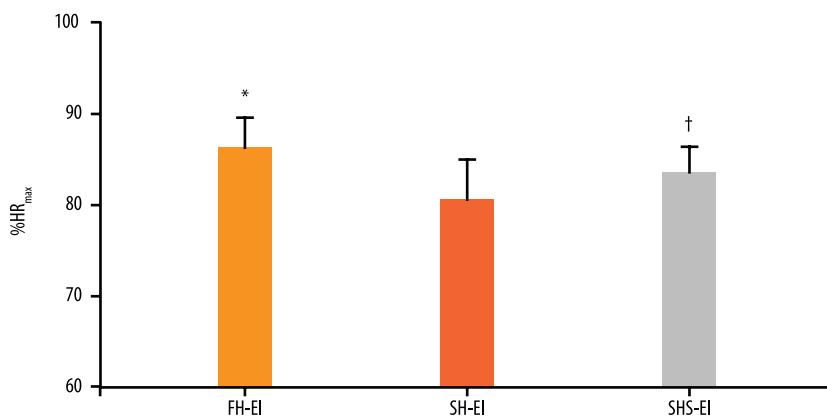
Situations	Match	Field test
HR <sub>max</sub>	200.2 $\pm$ 5.6	194.7 $\pm$ 5.5*
% players	83%	27%

\*Difference in comparison to Match ( $p < 0.05$ ).

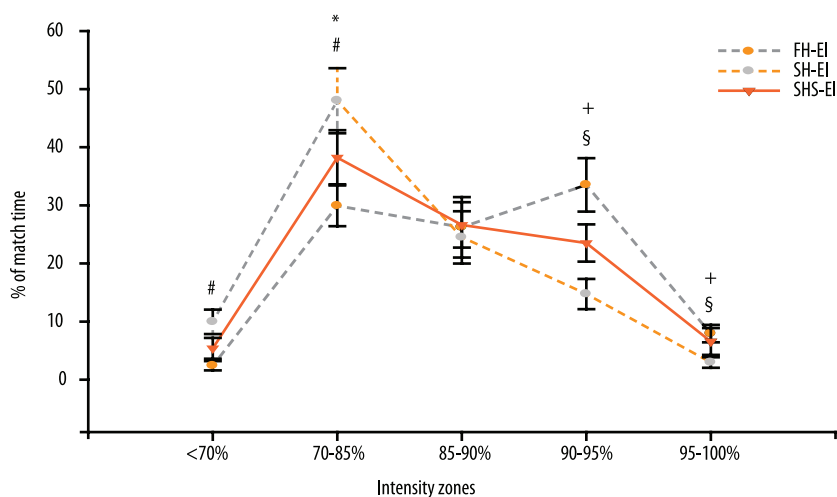
FH-EI was significantly higher than SH-EI and SHS-EI ( $p < 0.05$ ) (Figure 3). In addition, SHS-EI was higher than SH-EI ( $p < 0.05$ ).

Figure 4 shows the percentage of time spent during the game in different intensity zones. In the SH-EI situation, players spent a longer time in zone 1 when compared to FH-EI and SHS-EI ( $p < 0.05$ ). The percentage of time spent in zone 2 was higher for players in the SH-EI situation than for those in FH-EI and SHS-EI ( $p < 0.05$ ). Time spent in zone 2 was also higher

for players in SHS-EI than in FH-EI ( $p < 0.05$ ). FH-EI showed the highest percentage of time spent in zone 4 ( $p < 0.05$ ), and time spent in this same intensity zone was higher for players in SHS-EI than in SH-EI ( $p < 0.05$ ). FH-EI showed the highest percentage of time spent in zone 5 ( $p < 0.05$ ). Time spent by players in zone 5 was higher in SHS-EI than in SH-EI ( $p < 0.05$ ). Time spent in intensity zone 3 was not significantly different among EI groups ( $p > 0.05$ ).



**Figure 3.** Effort intensity (EI) as the percentage of maximal heart rate (%HR<sub>max</sub>) for the first-half effort intensity group (FH-EI), second-half effort intensity group (SH-EI), and second-half effort intensity group including substitutions (SHS-EI). \*Higher than SHS-EI and SH-EI. †Higher than SH-EI. Significance was set at  $p < 0.05$ .



**Figure 4.** Percentage of match time spent by players in different intensity zones according to the following situations: first-half effort intensity group (FH-EI), second-half effort intensity group (SH-EI), and second-half effort intensity group including substitutions (SHS-EI). #SH-EI higher than FH-EI and SHS-EI. \*SHS-EI higher than FH-EI. †FH-EI higher than SHS-EI and SH-EI. §SHS-EI higher than SH-EI. Significance was set at  $p < 0.05$ .

## DISCUSSION

The intensity of effort exerted by soccer players tends to decrease during the second half of a match, as shown in the present study (EI =  $86.3 \pm 3.3$  and  $80.6 \pm 4.4\%$ HR<sub>max</sub> for FH-EI and SH-EI, respectively,  $p < 0.05$ ). This decrease in EI was also demonstrated in our previous study<sup>10</sup>, suggesting the development of fatigue during the game<sup>1,20</sup>. Considering the impact of halftime substitu-

tions, we observed a significant EI decrease in the second half ( $p < 0.05$ ) in both second-half experimental groups (SH-EI and SHS-EI). However, EI decrease was attenuated by substitutions, with a higher EI in the SHS-EI than in the SH-EI situation ( $83.6 \pm 2.8$  and  $80.6 \pm 4.4\%HR_{max}$ , respectively,  $p < 0.05$ ).

The overall EI decrease can be interpreted as a decrease in the performance of players in the second half, possibly due to the development of fatigue during the game<sup>1,20</sup>. This effect has already been observed by other authors<sup>15,21</sup>, even when children were evaluated.<sup>6</sup> A common physiological explanation for this decrease in performance is the depletion of muscle glycogen during a soccer match, which, especially during the second half, would dramatically limit the player's ability to sustain high-intensity exercise<sup>20</sup>.

It should be considered that soccer players with higher levels of aerobic capacity are able to run longer distances<sup>22</sup>, usually take part in a larger number of decisive actions, and perform a higher number of sprints during the match<sup>8,23</sup>. Also, they have a shorter recovery time after sprints<sup>24</sup>, a lower decrease in performance during the second half<sup>4,25</sup>, and increased global performance during the whole match<sup>26</sup>. Based on that, it has been suggested that aerobic training should be emphasized in soccer in order to reduce the EI decrease that occurs during a match<sup>8,9</sup>. Moreover, by achieving and sustaining a better aerobic capacity, soccer players should be able to improve technical and tactical performance during the game<sup>26</sup>.

Several studies<sup>6,15</sup> have compared work intensity between the first and second halves of a soccer match using absolute values for mean HR in beats per minute (bpm). However, some authors point out that the relative HR should be considered as a percentage of  $HR_{max}$  in order to assess different athletes<sup>10</sup>, because HR shows different behavior for different individuals and under different environmental conditions<sup>13</sup>.

One study<sup>27</sup> evaluated soccer players during high-intensity activities (sprints) performed during a soccer match and found that the number of sprints performed by athletes who played only in the second half was higher than that of athletes who played the entire match. In addition, sprints occurred 35 to 45% less frequently in the last than in the first 15 minutes of the game.

Understanding the intensity of effort exerted by players during a soccer match is very important to gain tactical advantages<sup>21</sup>, especially when players are dismissed during the game<sup>16</sup>. Carling and Bloomfield<sup>16</sup> examined the effects of an early dismissal in a professional soccer match and found that the intensity of effort required from players was higher in the team reduced to 10 players. Therefore, a more precise understanding of this topic would certainly help coaches make better decisions to improve the performance of their teams.

When EI was analyzed as the percentage of time spent during the game in different intensity zones, we observed that soccer players spent a longer time at low-intensity zones (1 and 2) and shorter time at high-intensity zones (4 and 5) in the second than in the first half of the game ( $p < 0.05$ ). Helgerud et al.<sup>8</sup> reported similar findings and pointed out that intense aerobic training may attenuate the reduction observed in EI in the second half of a soccer game.

In the present study, when SHS-EIS and SH-EI were compared, time spent in high-intensity zones (4 and 5) was higher after player substitutions ( $p < 0.05$ ). This result corroborates our hypothesis that halftime substitutions may attenuate the reduction in EI. It was well demonstrated in this study that, when substitutions are made at halftime, players can sustain higher intensity exercise. It is known that soccer games are won by long-duration, high-intensity effort. Therefore, in a soccer match, substitute players are likely to be able to perform higher intensity actions than athletes who played the entire game, increasing the chance of winning. These observations also indicate the importance of considering substitutions when analyzing the intensity of soccer match play for the whole team, because players entering the field during the second half may perform higher intensity exercise, thus leading to an overestimation of overall match intensity.

A limitation of this study is that all substitutions analyzed were made at halftime. Therefore, our findings should be interpreted with caution, because in a real-life soccer game not all player substitutions are made at the same time or at halftime.

## CONCLUSIONS

A decrease in EI was observed in both second halves (SH-EI and SHS-EI) when compared to the first half (FH-EI) of soccer games. The drop in play intensity reported in the second half of soccer matches was attenuated by player substitutions made at halftime. The attenuated EI drop was also evidenced by the analysis of intensity zones, which revealed an increase in mean time spent in higher intensity zones (4 and 5) and a decrease in mean time spent in lower intensity zones (1 and 2) in the SHS-EI situation when compared to SH-EI. Therefore, when all substitutions are made at halftime, soccer players can sustain higher intensity actions, increasing the overall intensity of match play.

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