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original article

Neuromuscular profile of Handball players during a short-term condensed competition in Brazil

Perfil neuromuscular de atletas de handebol durante curta competição no Brasil

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Abstract – The aim of this study was to assess the neuromuscular profile of handball (TH) players during a short-term condensed competition. Nine TH athletes (age: 23 ± 3 years; height: 176.2 ± 10.5 cm; mass: 75.3 ± 8.6 kg) played 5 handball matches in 5 consecutive days and had exercise-induced muscle damage (EIMD) markers such as soreness (SOR), thigh circumference (CIR), knee range of motion (ROM) and countermovement jump height (CMJ) collected before the first match and at the end of each day of competition. Changes over time in these markers were analyzed. Significant changes were found for all EIMD markers assessed. CMJ significantly decreased at the fourth day of competition when compared to baseline (0.41 ± 0.03 m vs. 0.45 ± 0.02 m). ROM decreased on the first day of competition and remained stable until the last day of competition (baseline: 126.5 ± 7.2º; 1st day: 115.8 ± 5.9º; 2nd day: 115 ± 7º; 3rd day: 113.9 ± 8.8º; 4th day: 114.4 ± 8.6º). SOR and CIR were increased at the second day of competition and remained altered thereafter. It was concluded that the characteristics of short-term condensed competition have led TH athletes to significant EIMD. If not avoided, EIMD might lead to reductions in performance in the most important (final) matches.

Key words: Fatigue; Neuromuscular monitoring; Sports; Wounds and Injuries.

Resumo – *O objetivo do presente estudo foi medir o perfil neuromuscular de jogadores de handebol durante uma competição em formato de jogos. Nove jogadores de handebol (idade: 23 ± 3 anos; estatura: 176,2 ± 10,5 cm; massa: 75,3 ± 8,6 kg) jogaram cinco partidas da modalidade em cinco dias consecutivos e tiveram marcadores de DM [como percepção subjetiva de dor (PSD), circunferência da coxa (CIR), amplitude de movimento do joelho (ADM) e altura de salto com contra-movimento (AS)] coletados antes da primeira partida e ao final de cada dia de competição. Mudanças ao longo do tempo nesses marcadores foram analisadas. Alterações significantes foram encontradas para todos os marcadores de DM coletados. A AS diminuiu significantemente durante o quarto dia de competição, quando comparado ao valor basal (0,41 ± 0,03 m vs. 0,45 ± 0,02 m). A ADM diminuiu após o primeiro dia de competição e permaneceu comprometida até o último dia (basal: 126,5 ± 7,2º; 1º dia: 115,8 ± 5,9º; 2º dia: 115 ± 7º; 3º dia: 113,9 ± 8,8º; 4º dia: 114,4 ± 8,6º). A PSD e a CIR apresentaram aumento durante o segundo dia de competição e permaneceram alteradas até o final da mesma. Concluímos que a característica condensada das competições de handebol no Brasil leva a um quadro de DM significante. Se não evitado, o DM pode levar a comprometimentos no desempenho nas partidas mais importantes da competição (finais).*

Palavras-chave: *Esportes; Fadiga; Ferimentos e Lesões; Monitoração neuromuscular.*

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INTRODUCTION

Handball (TH) is a collective sport based on characteristics like court invasion, opposition between opponent players and collaboration between players of the same team, which are determinant to its unpredictable and complex scenario[1]. During matches, players perform different technical or strategic-tactical elements to score a goal (in the offensive phase) or avoid it from the opponent team (in the defensive phase).

Using spatial analysis, Bompa[2] stated that the oxidative system is responsible for 50% of the energy production during TH matches, with the other 50% being divided between ATP-CP system (20%) and anaerobic glycolysis (30%). In a more detailed investigation, Póvoas et al.[3] identified, also through spatial analysis, that TH players cover an average of 4.3 km during matches. According to the authors, athletes spend 80% of the total match time walking or standing still, while only 0.5% of the match time is dedicated to sprinting. The average heart rate obtained during matches was 139 bpm (72% of the maximal heart rate). These data support the knowledge that the oxidative metabolism is very important for TH players, aiding in optimal recovery in intervals between maximal efforts like sprints, jumps and throws. However, the two aforementioned studies described the efforts of TH players based on spatial analysis during matches, ignoring that, even while athletes are stationary, they usually perform maximal or near-maximal strength in struggles for space with opponents and/or marking and blocking. Therefore, although ignored by spatial analysis, explosive actions are of paramount for performance in TH.

Considering the high number of high-intensity motor actions and the vigorous energetic demands of TH, it is natural to expect the occurrence of EIMD after matches. EIMD is characterized as the disorganization of basic muscular units (sarcomeres) after performing high-intensity, eccentric-based exercises[4]. TH not only involves high-intensity efforts, known to induce EIMD, but it also requires players to perform considerable numbers of eccentric contraction, mostly with knee extensors, in actions such as sprints, landings (after jumps) and changing direction. The main symptoms assessed in order to identify and quantify EIMD are strength loss, compromised range of motion (ROM) and efficiency, leakage of intracellular proteins such as creatine kinase (CK) and myoglobin (Mb) to the blood stream, muscle swelling, and manifestation of delayed onset muscle soreness (DOMS)[5-9].

There is a gap of knowledge in literature about EIMD induced by TH matches. A study conducted by Michalsik, Aagaard & Madsen[10] investigated, through spatial analyses, fatigue manifestation during TH matches. Significant decreases in the number of potent actions were identified at the end of TH matches, which could indicate muscular fatigue, compromising optimal performance. However, EIMD differs from fatigue, since it occurs when the muscle tissue is disrupted, while fatigue is often related to energetic substract depletion and/or central factors that lead to altered motor

unit recruitment[11]. There is an increasing number of studies investigating EIMD response after a number of athletic activities such as marathon[12,13], soccer[14,15], basketball[16-17], and tennis[18] matches. However, these data cannot be extrapolated for TH, since this sport has very specific aspects related to performance and metabolism (i.e., powerful actions and resistance simultaneously). Moreover, many competitions (especially in semi-professional and amateur levels) present condensed schedules that do not allow sufficient recovery periods between matches, which could compromise proper recovery from EIMD.

Considering the above, it has been hypothesized that, during short-term condensed competitions, the performance levels of TH athletes would be compromised by EIMD. Therefore, the aim of this study was to monitor classical EIMD symptoms of TH athletes throughout the Regional Games, a competition characterized as having very short interval (i.e., approximately 24 hours) between matches.

METHODS

Fourteen male athletes, members of a college TH team, participated in the competition. Their regular training regimen consisted of 3 to 4 two-hour training weekly sessions and had at least 5 years of experience as handball players. The team under study finished competition at the fourth place, out of 13 participating teams. Athletes that played less than 25 minutes (complete period of the game) (n=4), and suffered from articular injury (n=1) were excluded from the sample. Therefore, considering the exclusion criteria, nine out of the fourteen team members composed the sample. Their mean age, body mass and height were 23 ± 3 years, 75.3 ± 8.6 kg and 176.2 ± 10.5 cm, respectively. All experimental procedures were conducted in accordance to the Declaration of Helsinki and all participants spontaneously consented on taking part in this investigation. The study protocol was approved by the Ethics Research Committee (CAAE number: 33739614.1.0000.5465).

All athletes performed anthropometric (weight, height, circumference and range of motion), jumping performance, and soreness perception tests at the end of each day of competition. No tests were conducted at the end of the last day of competition, since athletes had already left the concentration site. Baseline assessments were performed at the night before the first day of competition. During the competition period, assessments were performed every day at 09:00 pm with a flexibility of ± 1 hour. The assessment time was fixed at this time point in order to avoid changes related to physiological fluctuations related to the circadian rhythm[19]. All assessments were performed at least two hours after the end of matches and the players did not use any recovery strategy during the competition period. The match and assessment schedule is represented in Table 1.

Table 1. Schedule of assessments, time of the day in which matches were performed and results of matches along the competition. W: Win; L: Loss.

	Baseline	Day 1	Day 2	Day 3	Day 4	Day 5
Match Time	-	10:00	19:00	19:00	15:00	15:30
Assessment Time	21:00	21:00	22:00	22:00	20:30	-
Match Results	-	W (36x11)	W (37x19)	W (30x23)	L (24x28)	L (20x23)

Four different neuromuscular function variables were assessed, all of them related to the diagnosis and quantification of EIMD. All measurements were performed and repeated by the same professional in a randomized design in order to guarantee validity and reproducibility.

Perceived Muscle Soreness (SOR) was assessed through a test in which athletes sat and raised from a 45 bench without any assist from the arms. Their perceived soreness was then marked on a Visual Analogs Scale (VAS), which ranged from 0 (not sore at all) to 100 (very, very sore) in millimeters[20]. All subjects were oriented to mark the scale considering only muscle soreness, disregarding articular and other types of pain.

Muscle swelling was measured by alterations in Circumference (CIR) of the mid portion of athletes' thighs (50% of the distance between the greater trochanter and the lateral condyle of the femur). All CIR measurements were performed with an anthropometric tape measure.

The Range of Motion (ROM) of the knee articulation was assessed with a commercial plastic goniometer (CARCI, São Paulo – Brazil). ROM was calculated as the difference between maximal knee flexion (MKF) and maximal knee extension (MKE), considering the anatomic position of the knee as 0º[21]. MKE was assessed when athletes tried to maximally extend the knee, while MKF was measured when they tried to maximally flex the knee. Both measurements were conducted with subjects in standing position.

Countermovement Jump Height (CMJ) was adopted as a power output measurement and was determined by kinematic analysis. In order to assess CMJ, all athletes wore tight black shorts marked by a circular, photo-reflective, white marker placed at the greater trochanter (não entendi). A video camera (HERO 3 – GoPro, San Mateo - USA) was placed and calibrated within 3 meters from the subjects on the sagittal plane. Athletes were then oriented to jump as high as possible, applying countermovement, with their hands on their hips. All jumps were recorded in high definition (1280x720p) at a frequency of 120 fps and saved for further analyses. The videos obtained were transferred to the VirtualDub (VirtualDub, Boston - USA) software and analyzed in the PeakMotus (Vicon, Denver - USA) software. CMJ was calculated as the difference between the white marker on the height of the greater trochanter when standing still and at the highest point of the jump.

All variables that attended to the sphericity assumption through Mauchly's test were analyzed via one-way, repeated measures, analyses of variance (ANOVA), followed by post hoc Tukey's test. The other variables were analyzed with the Friedman test, followed by Wilcoxon's test, to identify differences through time. Parametric data are represented as means and standard devia-

tion, while nonparametric data are represented by medians and interquartile variation. All statistical analyses were performed in the STATISTICA 7.0 software (Statsoft, Boston – USA). Significance levels of $p < 0.05$ were adopted.

RESULTS

A significant time effect was identified for SOR throughout the competition ($x^2 = 18.66$; $p < 0.001$). Values obtained at the second ($M_d = 8$ cm; IQR = 7 cm), third ($M_d = 5$ cm; IQR = 13 cm) and fourth ($M_d = 8$ cm; IQR = 17 cm) days of competition were significantly greater ($p < 0.05$) than baseline values ($M_d = 0$ cm; IQR = 0 cm) and those obtained at the first day of competition ($M_d = 0$ cm; IQR = 1 cm). SOR values are represented in Figure 1.

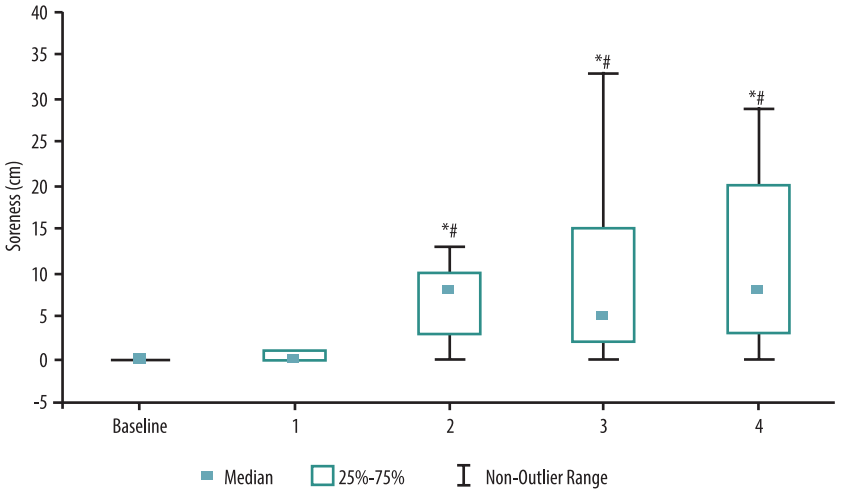

Figure 1 – Soreness values assessed at baseline and at the end of each day of competition. * $p < 0.05$ compared to baseline; # $p < 0.05$ compared to the first day.

Significant differences through time were also identified for CIR ($x^2 = 17.55$; $p = 0.001$). CIR values assessed at the second day of competition ($M_d = 55$ cm; IQR = 4.8 cm) were significantly greater ($p < 0.05$) than those obtained at baseline ($M_d = 54.5$ cm; IQR = 3.8 cm) and on the first day of competition ($M_d = 54$ cm; IQR = 5 cm). Moreover, CIR values measured on the third ($M_d = 55.8$ cm; IQR = 5.5 cm) and fourth ($M_d = 56$ cm; IQR = 6.5 cm) days were significantly higher than those obtained earlier on competition. All CIR values are represented in Figure 2.

Considering ROM values, a significant time effect was identified throughout the competition ($p = 0.004$; $F = 4.4$). Post hoc analysis showed significant differences ($p < 0.05$) between ROM values obtained on the first (115.8 ± 5.9º), second (115 ± 7º), third (113.9 ± 8.8º) and fourth (114.4 ± 8.6º) days of competition when compared to baseline values (126.5 ± 7.2º). ROM variations are represented in Figure 3. A significant time effect was identified for CMJ values throughout the competition ($p = 0.047$; $F = 2.64$). CMJ values at the fourth day of competition (0.41 ± 0.03 m) were significantly lower ($p < 0.05$) than baseline values (0.45 ± 0.02 m). All other values were not statistically different from each other. Figure 4 represents CMJ values throughout the competition.

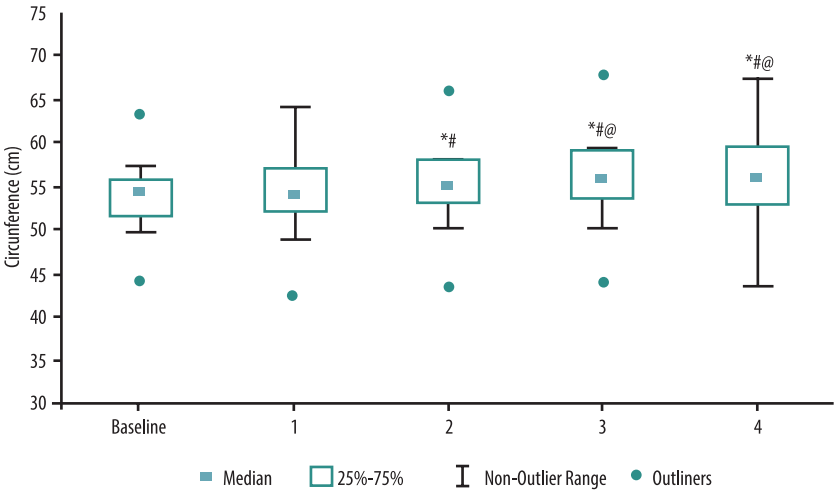

Figure 2 – Circumference values assessed at baseline and at the end of each day of competition. * $p < 0.05$ compared to baseline; # $p < 0.05$ compared to the first day; @ $p < 0.05$ compared to the second day.

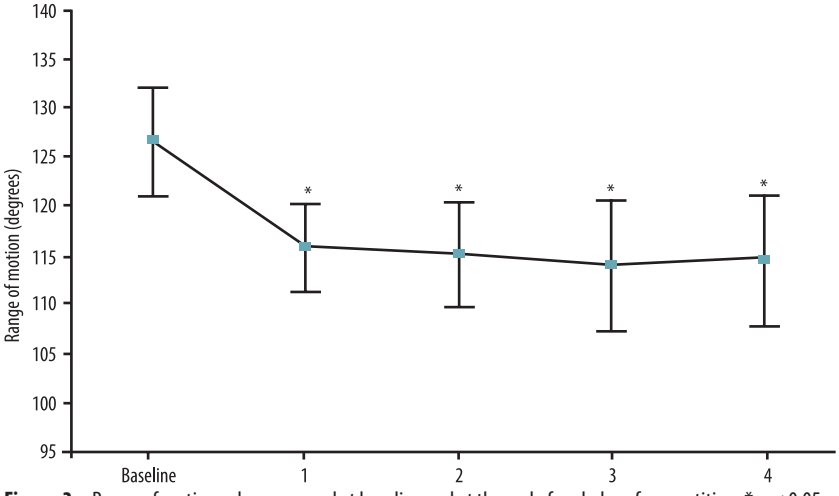

Figure 3 – Range of motion values assessed at baseline and at the end of each day of competition. * $p < 0.05$ compared to baseline.

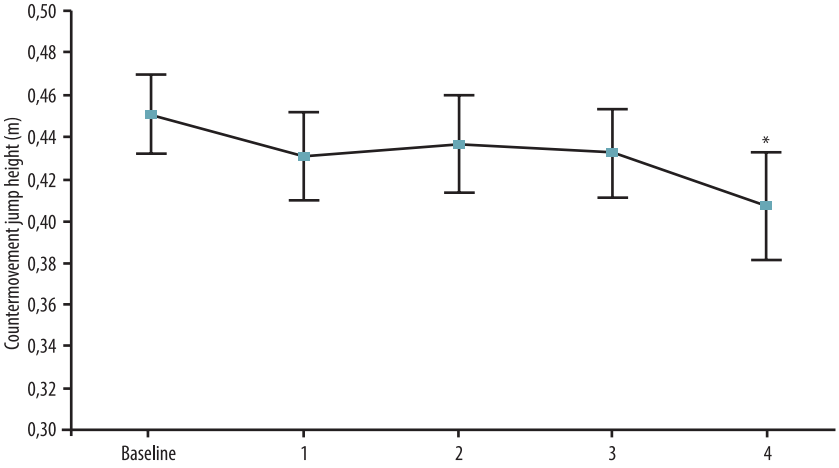

Figure 4 – Countermovement jump height values assessed at baseline and at the end of each day of competition. * $p < 0.05$ compared to baseline.

DISCUSSION

The aim of our study was to assess the neuromuscular profile of TH athletes during a condensate, short-term, competition, testing the hypothesis that EIMD would compromise athletic performance by altering four markers that are related to strength and technical performance. Our findings pointed to significant changes in all symptoms over time and, more importantly, during the last stage of competition.

It has been previously established that sports that require high number of powerful and intense actions lead to EIMD[14-18]. However, to the best of our knowledge, there are no studies investigating the effects of TH matches on EIMD markers and, most importantly, subsequent performance. In our study, alterations in four frequently assessed EIMD markers (SOR, CIR, ROM and CMJ) were identified throughout the competition. However, an addition effect might have led to greater changes in EIMD markers that would not be manifested after a single match, as previously described in a similar model[22]. However, considering that the most important TH competitions have a short-term, condensed characteristic[23], it is also important to investigate the level of stress imposed to the neuromuscular system throughout them.

As shown in Figure 1, SOR levels significantly increased at the second day of competition and remained increased until the last assessment. This late development of SOR has been widely reported in EIMD studies and occurs due to a relatively slow response of the immune system to disruptions in the ultra-structural muscular components, characterizing the term "delayed onset muscle soreness"[5]. Although it is common to observe a peak in SOR 48 hours after a damaging bout, it tends to decrease and be fully recovered 4 to 5 days after it[21]. We believe that SOR remained increased throughout the competition due to the aforementioned addition conferred by subsequent matches (damaging bouts). Moreover, Nelson[24] states that increased SOR can compromise the performance of high-intensity and technical activities and should be avoided by coaches and trainers during competitions. Additionally, although not systematically assessed, SOR was reported by athletes to coaches during the two final competition matches. Therefore, it is reasonable to assume that the changes found in SOR in the present study might have influenced performance and disposition during the competition.

Similarly to SOR, CIR presented its first significant increase in the second day of competition (Figure 2). However, on the third and fourth days of competition, CIR was significantly greater than in all previous days. It is common for CIR to respond similarly to SOR, since both are triggered by the inflammatory response to EIMD. CIR is actually an indirect measurement of edema caused by inflammation[4,16]. However, it increased to an extent that SOR did not. We believe that this dissociated response might be justified by the fact that CIR is an objective, biological measure, while SOR, being a subjective marker, might have been influenced by the

athletes' mood state, previous exposition to soreness and personality, as previously described [24].

As graphically represented in Figure 3, the ROM of athletes' knee was significantly different than baseline values in all days of competition. These changes were also expected, considering the intensity of matches and the manifestation of EIMD. Along with the other variables, and additional damaging effect was also identified throughout the competition. ROM is usually used as an indirect marker of muscle passive stiffness in studies that investigate EIMD[4,20,21]. Increased stiffness has been demonstrated to compromise efficiency of the stretch-shortening cycle[25,26]. Running, jumping and tackling are considered as key actions for successful performance in TH and require great levels of muscular power, which is optimized by the stretch-shortening cycle[27]. Therefore, if the power generating capacity of knee extensors is compromised by muscular stiffness (induced by EIMD), decreases in performance might occur.

CMJ presented a different behavior, compared to the other EIMD markers surveyed. As shown in Figure 4, the only time-point in which athletes presented decreased jump height was on the fourth day of competition. However, although no significant differences were found, CMJ presented a slight decrease on the first day of competition, remaining below baseline values up to the third day and, finally, falling to a significantly different level on the fourth day. We believe that this significant decrease might have occurred due to the aforementioned addition effect [22], in which subsequent ruptures on the muscular ultra-structural components kept weakening the athletes' muscles up to a point in which it produced significant less power and, consequently, a shorter jump height. It is important to state that assessments were performed with athletes jumping with both limbs. However, during matches, athletes usually use only the non-dominant limb to perform jumps and landings.

Since CMJ was the only assessment performed in a bilateral mode, the non-jumping limb might have biased the measurement result. However, both limbs perform explosive actions like running and tackling during matches. Therefore, it could be inferred that strength production was not as affected by the first three matches as much as the other EIMD markers. Notwithstanding, strength performance was compromised after the fourth match, which lead athletes to play the final, and most decisive match, in a compromised state. Considering that jumping is a very important action for TH, we believe that performance on the last match of the competition might have been lower than expected due to EIMD.

Considering the alterations in parameters collected, coaches should focus on preparing their athletes to resist the damaging situations inherent to this type of competition. Literature provides many strategies to protect the neuromuscular system from EIMD, like performing a high-intensity damaging bout previously to the competition[6], performing maximal isometric contractions a few days before it[28], improving the athletes flexibility through training[29] and even providing anti-oxidant supplements for

athletes before and during the competition[30]. Another action that should be considered by the organization of such sports events is to extend the competition calendar in order to allow at least 48 hours of rest between matches. However, we believe that this alternative is far from possible, considering the necessary logistics.

Finally, there are important limitations in the present study. The number of athletes that completed the testes was relatively low, which may have led to a type II error. A relatively high number of athletes (n = 14) volunteered for the study. However, four of them did not play more than 25 minutes during matches, which was considered insufficient for concrete manifestation of EIMD and fatigue, and another athlete was injured during the competition, not being able to complete all tests. Athletes from other teams could have been selected to participate in the present study in order increase statistical power and, most importantly, analyze the effects of this short-term competition in the neuromuscular profile of athletes that performed different training protocols and played at different positions in the competition. However, in order to assess so many different athletes, larger research team and the approval from different coaches and delegations would be required. The bilateral strength assessment protocol might have contributed to the unconventional data obtained for CMJ. Further studies should focus on examining the most commonly used limb. Also, match intensity was not controlled through spatial analyses or heart rate monitoring. Unfortunately, heart rate monitoring cannot be performed during official TH matches due to the potential hazard that the harness might provide to athletes and spatial analyses requires authorization from other athletes and from the organization of the competition. Finally, matches were played at different times of the day, which might have influenced performance in the matches and assessments. However, this is a reality in most competitions and more accurately reflects neuromuscular changes when compared with highly controlled protocols with standardized time between sessions.

CONCLUSIONS

It could be concluded that the short interval periods between TH matches in a short-term condensed competition can lead to insufficient recovery and, therefore, EIMD. The elicited EIMD was proven to be related to decreases in performance in the final and most important matches of the competition, in which athletes are expected to perform their best. We recommend that coaches focus on prevention strategies against EIMD, which are abundant in literature.

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