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REVIEW ARTICLE

DIAGNOSIS, PREVENTION, AND TREATMENT OF OVERTRAINING SYNDROME IN WOMEN'S SOCCER

DIAGNOSTYKA, PROFILAKTYKA I LECZENIE SYNDROMU PRZETRENOWANIA W PIŁCE NOŻNEJ KOBIET

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ABSTRACT

Aim

This review aims to collect available publications referring to the diagnosis, prevention, and treatment of OTS in women's soccer and assess its quality and practical applications and verify whether there are any scientific data analyzing the potential association between OTS and injuries.

Material and methods

Relevant articles were selected by computer search in two databases – PubMed and Web of Science – using the keywords 'over-train' or 'overtrain' and 'football' or 'soccer'. The quality evaluation of included papers was performed.

Results

A total of 215 records were obtained, but ultimately, only 4 eligible articles were included. Pre-post publications scored a fair quality rating and the case series study scored a good quality rating.

Conclusions

The diagnostic methods – biomarkers monitoring and performance testing – lack the accuracy, specificity, and repeatability that good-quality clinical trials should have. As for prevention, supplementation and recovery strategies were proposed, but they have no confirmed application in real life. No treatment information and no data analyzing the potential association between OTS and injuries were found. Despite promising results, researchers are still unable to link them directly to OTS, so more studies are needed.

Keywords: overtraining, soccer/football, athlete monitoring, biomarkers, fatigue

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STRESZCZENIE

Cel

Niniejszy przegląd ma na celu zebranie dostępnych publikacji dotyczących diagnostyki, profilaktyki i leczenia syndromu przetrenowania w kobiecej piłce nożnej oraz ocenę ich jakości i praktycznego zastosowania oraz zweryfikowanie, czy istnieją dane naukowe analizujące potencjalny związek między OTS a kontuzjami.

Materiał i metody

Odpowiednie artykuły zostały wybrane za pomocą wyszukiwania komputerowego w dwóch bazach danych – PubMed i Web of Science – przy użyciu słów kluczowych „over-train*" lub „overtrain*" oraz „football" lub „soccer". Przeprowadzono ocenę jakości wybranych artykułów.

Wyniki

Uzyskano 215 pozycji, ale ostatecznie uwzględniono tylko 4 kwalifikujące się artykuły. Trzy publikacje (pre-post study) uzyskały średnią ocenę jakości, z kolei czwarty artykuł (case series) został oceniony jako dobry.

Wnioski

Metodom diagnostycznym – monitorowaniu biomarkerów/zmęczenia i testom wydajności – brakuje dokładności, specyficzności i powtarzalności, które powinny mieć dobrej jakości testy kliniczne. W zakresie profilaktyki zaproponowano suplementację i strategie regeneracji, jednak nie mają one potwierdzonego zastosowania w praktyce. Nie znaleziono informacji o leczeniu ani danych o możliwym związku OTS z kontuzjami. Pomimo obiecujących rezultatów, naukowcy nadal nie są w stanie powiązać ich bezpośrednio z syndromem przetrenowania. Dalsze badania są konieczne.

Słowa kluczowe: przetrenowanie, piłka nożna, monitorowanie sportowców, biomarkery, zmęczenie

Introduction

Overtraining syndrome (OTS) is always a potential risk to those who train hard and compete. With inadequate recovery time, many highly stressful situations, and frequent injuries, both physical and mental health takes a toll. Athletes are known for pushing their limits and it's both a show of their dedication and investment but it's also a risk. Excessive training intensity without proper monitoring of the physical or psychological signs of stress leads to an imbalance between training and recovery, which in turn leads to a decrease in performance (Halson, 2014). All of this is closely related to OTS, but it's not only that. Many studies mention even more dangerous symptoms like weight loss, mood disturbances, insomnia, depression, or chronic fatigue (Kreher, 2016). Adding to that wide range of possible yet not proven causes (Weakley *et al.,* 2022), OTS is still kind of an unknown for researchers.

It's mainly defined as a long-term decrease in performance, an accumulation of under-recovery and it's marked by various symptoms (Kellman *et al.,* 2018), some of them listed above. OTS precedes non-functional overreaching (NFOR) and the major difference between them is time – counted in months of recovery for OTS (Meeusen *et al.,* 2013). It was suggested to use ACTH and prolactin responses to exercise to distinguish those two (Meeusen *et al.,* 2010)(Buyse *et al.,* 2019). The greatest challenge in understanding OTS is its heterogeneity. A single marker is not enough to issue a diagnosis, regardless of the selected

method (Cadegani *et al.,* 2020). And since no tool confirms the occurrence of OTS, the only way to identify it is to rule out all other possible causes (Meeusen *et al.,* 2013).

According to Rodrigues *et al.* (2023), there is some evidence that supports a link between the intensity and volume of football sessions, symptoms of overtraining, and injuries. By utilizing factor analysis and a structural equation model to analyze all of the variables, the authors found that training frequency was significantly related to overtraining symptoms, which in turn were significantly linked to a higher number of injuries. Additionally, training experience was found to have a negative association with overtraining symptoms but a positive association with the number of injuries (Rodrigues *et al.,* 2023).

However, it has to be underlined that, despite a growing number of articles regarding OTS and its potential interior with injuries, many of them focus solely on men, leaving out a large part of the population (Castello *et al.,* 2014), making it hard to find validated information on female athletes, when knowing that women are more at risk (Matos *et al.,* 2011). Therefore, this review aims to collect available publications referring to the diagnosis, prevention, and treatment of OTS in women's soccer and assess its quality and practical applications. We also wanted to verify whether there are any scientific data analyzing the potential association between the OTS and number and characteristics of injuries sustained by female players.

Methods

Search strategy and selection

Relevant articles were selected by computer searches in two databases – PubMed and Web of Science – using the keywords 'over-train*' or 'overtrain*' and 'football' or 'soccer'. The search was narrowed down to the last 10 years. It was performed on October 2022. There were no records from additional sources.

These publications, in the initial stage of selection, were checked in terms of the above keywords, first in the title itself, then in the abstract. After excluding ineligible studies – the ones that did not contain an appropriate study group or did not address overtraining – the remaining papers were downloaded as full text. The final decision to include/exclude articles was made by the main author based on the criteria listed and detailed below. Then the quality evaluation of included papers was performed.

Selection criteria

Participants

Studies that included only women and those that involved both women and men were included if the participants were grouped and studied separately. Articles that focused solely on youth (under 18) were excluded. The selection included only football players – other sports were excluded, including futsal, Gaelic football, and beach soccer.

Type of study

All types of studies were included, except for descriptive studies, systematic and brief reviews. Articles were considered if published in English within the last 10 years.

Intervention

The publications were qualified if they broadly referred to the diagnosis/prevention/treatment of the overtraining syndrome (OTS), taking into account the monitoring of players' fatigue, both physical and mental, as well as assessing the athlete's health and optimizing the effectiveness of training.

Quality assessment

Two scales were used to assess the quality of selected papers – Quality Assessment Tool for Before-After (Pre-Post) Studies With No Control Group and Quality Assessment Tool for Case Series Studies, which were taken from the website of the National Institute of Disease of the Heart, Lungs, and Blood (NHLBI) of the United States[1]. They were selected based on

1 https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools (z dnia 20.12.22)

the type of study (Ma *et al.*, 2020). The overall quality rating of Pre-Post studies was based on a number of missing items: 0–3 good quality with a low risk of bias, 4–8 fair quality with moderate risk of bias, and 9–11 poor quality with a high risk of bias (Devane *et al.*, 2022). The overall quality ranking of the case series study was based on answering questions 1.6 and 9, as they were the most important. If all of them were present the quality was good, if 1 was missing the quality was fair, and poor when 2 were not present (Reus *et al.*, 2018). Tables 1 and 2 present the detailed criteria and evaluation of selected articles. Two raters independently assessed the methodological quality of selected articles.

Results

Study selection

The detailed process of the search is presented in Figure 1. A total of 215 records were obtained. After excluding papers older than the last 10 years and rejecting duplicates, there were 123 records. They were screened based on title, then on abstract, and at last on full text. Ultimately there were 4 eligible articles included. Three of them are pre-post studies and one is a case series. None of them has a control group. A summarized description is provided in Table 3.

Outcomes

Participants

Participants were mainly female gender. Only Chamera *et al.* had a mixed group, dividing subjects based on their sex. All of the participants were young adults playing football.

Walker *et al.* gathered 25 high-level Division I female soccer players with an average age of 20 years. Participants were instructed not to change their diet. All of them were cleared by the medical staff before intervention.

Chamera *et al.* enlisted 16 athletes, 8 female from Olimpia Szczecin, with an average age of 21.9 years, and 8 male soccer players from Pogoń Szczecin, with an average age of 18.4 years. Subjects had been instructed not to take medications/supplements that could affect metabolism. They also were non-smokers and without metabolic/cardiovascular diseases in their history.

Luke *et al.* recruited 16 football players from Division II women's team in the United States of America. Participants were students at a university in California. They were divided into 2 groups: starters, an average age of 20.5 years, and non-starters, an average age of 21 years.

In an article by Baghaei *et al.* fifteen female players participated, but three of them dropped out due to injury. All of them had at least three years of experience. They also reported no drug use during the study.

Types of interventions

There were different types of interventions presented, but each included biomarker monitoring. Walker *et al.* and Luke *et al.* both carried out performance testing with vertical jumps evaluation. Luke *et al.* also focused on the assessment of mental and physical fatigue. Chamera *et al.* analyzed only the liver profile. Baghaei *et al.* focused on cortisol, heart rate and subjective measurements e.g. quality of sleep or appetite.

In an observational study by Walker *et al.*, 25 Division I female soccer players were included in performance testing, season training monitoring, and blood sample collections. Performance testing consisted of 3 attempts of Vertical Jump, assessment of body composition, maximal aerobic capacity (Vo2 max), and heart rate (HR). Individual workload (TL), energy expenditure (EEE), and HR were monitored during all practices and games. Every 4 weeks blood samples were collected and a combination of biomarkers was analyzed – free and total Cortisol (CORTF/CORTT), Prolactin (PRL), Triiodothyronine (T3), Interleukin 6 (IL-6), Creatine kinase (CK), Sex-hormone binding globulin (SHBG), Omega-3 (n-3FA), Vitamin D (Vit-D), Iron (Fe), Hematocrit (HcT), ferritin (Fer), Saturation (% Sat), Total iron-binding capacity (TIBC).

Chamera *et al.* in a pre-post study conducted a 60-minute run on the last day of the training

season. 16 participants from football clubs were divided into 2 even groups, based on their sex. Subjects were told to maintain individually calculated subliminal heart rates (about 158). Blood samples were obtained before and immediately after the run. The activity of aspartate transaminase (AST), alanine transaminase (ALT), gamma-glutamyl transpeptidase (GGT), CK, and levels of bilirubin were analyzed.

In the publication by Luke R. *et al.,* 16 athletes from Division II women's soccer team were monitored for 10-week time (preseason, competitive season, and post-season) – authors weekly measured vertical jump, levels of salivary cortisol, body weight, and both mental (RMF) and physical (RPF) fatigue in the form of survey (0 = no fatigue, 10 = almost maximal fatigue).

Baghaei *et al.* observed female players for 6 month time, starting 3 weeks before the season and finishing at the end of the season. Measurements were taken pre-, mid- and post-season. Cortisol levels, length of sleep, resting heart rate, quality of sleep, tiredness sensation, training willingness, appetite, competitive willingness, muscle soreness and SFMS questionnaire (The Société Francaise de Médicine du Sport Questionnaire) scores were examined.

Diagnosis

The diagnosis mainly focused on detecting predictors of underperformance and underrecovery. Each study addressed a different combination of biomarkers. Additionally, Luke *et al.* and Baghaei *et al.* also followed the mental and physical fatigue of the players.

Walker *et al.* in their publication indicate that the decrease in performance testing (weight, %BF, Vo2 max, VJ) at post-season, along with an accumulation of TL and EEE, are proof of cumulative stress or insufficient recovery, manifesting at the most competitive time of the season. Chronically high cortisol levels were observed throughout all five blood collections, elevating in two peaks close to the end of the season. After the highest TL was noted there was no immediate answer in cortisol levels. The other parameters – IL6 as a marker of inflammation and CK as a hormone responding to stress – raised at the end, revealing, that subjects also experienced a hormonal response to an accumulation of exertion. SHBG didn't change, but PRL increased in the middle and remained elevated. The authors concluded that biomarker monitoring in combination with TL tracking may allow providing better management, as they show body response to pressure and readiness to play and compete.

Chamera *et al.* provided information that the values of CK did not change after the run, contrary o AST and ALT values, which increased but only in female participants. It was suggested to use those enzymes to avert a decrease in fitness levels, as they are seen faster than CK. The authors concluded that the increased GGT might also be a good marker of organism response to activity, as it's not only connected with muscle but also with liver metabolism – and it's associated with high physical effort. Non-enzymatic liver parameters were not a good match as markers, not only because they're hard to collect, but because there were no changes found in total and direct bilirubin.

Luke *et al.* found no significant dissimilarity in performance testing throughout the season, but fatigue scales displayed a difference between specific time points (week to week) – RPF peaked mid-season for both groups and then declined, while RMF followed the same pattern, but with an earlier peak and decline, meaning that mental fatigue preceded physical fatigue. Participants' perceived physical and mental fatigue diminished at the end of the season, which was explained by using effective recovery strategies by the coaching staff.

In the study by Baghaei *et al.,* the authors found a significant and positive correlation between cortisol levels and SFMS questionnaire scores at the end of the season, which confirms the need to use both objective and non-objective measures for the diagnosis

of OTS. An increase in resting heart rate was reported, but there was no conclusion to an exact reason for it. As for the rest of the subjective variables (quality of sleep, tiredness sensation, training willingness, appetite, competitive willingness and muscle soreness), they decreased over the duration of the season.

Prevention

As for prevention, each study had its own approach. Supplementation was given attention to. The authors also considered more thorough communication with players and some recovery strategies as possible solutions.

Walker *et al.* presented the highest TL and EEE levels during the preseason. It was written that the increase in CK at the start, along with high TL values, may indicate, that this short and tough period, might have a disadvantageous impact on players. In such moments more recovery strategies may be needed. It was also mentioned that iron (Fe) at the end of the season was 56% lower than the initial values, making it impossible for participants to maintain their performance and aerobic capacity. Supplementation of Fe, Omega-3, and Vit-D may benefit female athletes and provide better conditions for much-needed recovery, as n-3FA and Vit-D levels also dropped down.

Luke *et al.* encourages communication with athletes. The authors state that being aware of the physical and mental status of the players may be enough to prevent a breakdown, by simply modifying practices or reducing athletes' concerns. The strategies mentioned are: motivating to effective rest, developing mental skills/routine, giving recovery time before any competition, limiting distractions, and fostering athletes' determination.

Treatment

None of the selected publications mentions any possible treatment of the overtraining syndrome.

Study quality

Tables 1 and 2 present the criteria and assessment of the articles. Pre-post publications scored a fair quality rating and the case series study scored a good quality rating. Pre-post studies were not blinded and measures were taken only once. None of the included studies had enough participants to provide confidence in the outcomes, as the biggest study had only 25 participants. Studies were overall well-described, both in the intervention and result section and for those criteria, they got points. In the case series study, a description of statistical methods was missing, but still, the article got the highest rating of them all. The reviewers independently assessed the methodological quality of selected articles with a compliance level of 88%. If needed, an agreement was reached by discussion.

Discussion

This review aims to collect available publications referring to the diagnosis, prevention, and treatment of OTS in women's soccer and assess its quality and practical applications. From the search of the literature, only a small number of publications met the criteria. The sheer number of studies found suggests that the female gender is very backward in terms of information availability compared to the male population. There was also no data in selected articles analyzing the potential association between OTS and injuries.

All publications described in this review have a study group whose size does not indicate credibility in the outcomes. Additionally, participants were athletes, which means that their profession predisposes them to OTS. However, it does not equate to whether they will be affected by it. So it is impossible to say how the results apply to those who are actually affected since it was carried out on healthy individuals.

OTS is a perplexing state, extensive and non-specific. The results of biomarker utilization with TL tracking, which are given in this review, show promise. But still, those diagnosis methods can detect only predictors

of under-recovery or underperformance, as numerous studies have done before (Cadegani *et al.,* 2017). They are still not specific and accurate enough for OTS, just the same as liver enzymes in the study of Chamera *et al.*

Nonetheless, the given data might support the football coaching staff managing elite female players, especially those related to the psychological aspect. It was proven that conflicts with management, and not enough support from coaches, were the two most important reasons for lows in the mood of female football players (Prinz *et al.,* 2016). At least, compared with blood tests, more frequent communication and other mentioned strategies (e.g. reducing distractions during practices), are free, easy to apply, and undemanding.

The publication of Walker *et al.* showed the need for supplementation of Vitamin D in female athletes. It was already mentioned in other studies, that vitamin D is a major factor in assisting bone growth and preventing stress factors, it also aids electrolyte metabolism and immune function, so it should be maintained at optimal levels > 40 ng/mL (Ogan *et al.,* 2013). As for the iron decrease, there is contradictory information about the improvement of athletes' performance after its supplementation (Rubeor *et al.,* 2018).

There was no information found regarding the treatment of OTS. In other studies, it was suggested that relative or complete rest is the answer – depending on the internal or external motivation of the individual (Kreher *et al.,* 2012).

As for the limitations, few studies are focusing only on women. They're also small in participant numbers. It might be beneficial to at least expand the number of searched databases to find a greater amount of records with more variety of keywords. Different languages should be also considered. The female menstrual cycle can be a significant variable, but it was taken into account only in the article by Baghaei *et al.* The same applies to sleep and diet monitoring (Cadegiani *et al.,* 2020).

Conclusion

The mechanisms of overtraining syndrome are still too complex for researchers to understand. The diagnostic methods found in this review lack the accuracy, specificity, and repeatability that good-quality trials should have. As for prevention, it has no confirmed application in real life. No treatment information and no data analyzing the potential association between OTS and injuries were found. Despite promising results, researchers are still unable to link them directly to OTS. More research is needed for confirmation and credibility purposes.

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