University of Trás-os-Montes e Alto Douro

EFFECTS OF PELVIC FLOOR MUSCLES TRAINING ON PREVENTION AND TREATMENT OF STRESS URINARY INCONTINENCE IN ATHLETES

Doctoral Thesis in Sports Sciences

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Vila Real, 2020

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I dedicate this work to my daughters, my husband, my parents, my brothers and my nephews.

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Life gives us the opportunities,

we make them happen...

PALAVRAS-CHAVE Atletas; Exercícios de alto impacto; Fisioterapia; Incontinência urinária de esforço; Músculos do Pavimento pélvico; Nulíparas.

RESUMO A evidência científica tem demonstrado uma forte associação entre a prática desportiva e a prevalência de incontinência urinária de esforço (IUE). Investigações recentes têm evidenciado que a IUE afeta cada vez mais jovens atletas e nulíparas. A prática de exercícios de alto impacto aumenta a pressão intra-abdominal afetando as estruturas do pavimento pélvico. Adicionalmente, estudos demonstram que a qualidade de vida (QoL) das atletas com IUE é, muitas vezes, afetada, podendo levar ao abandono da prática desportiva. Face ao exposto, a fisioterapia tem um papel fundamental na reabilitação dos músculos do pavimento pélvico (MPP), sendo considerada a primeira linha de tratamento com evidências de nível A. Destaca-se no tratamento desta disfunção, um protocolo de treino dos músculos do pavimento pélvico (TMPP). Assim, para tornar as intervenções mais eficazes, considerou-se pertinente o estudo mais detalhado da IUE em atletas, abordando a prevalência, os fatores de risco, as medidas preventivas e o tratamento, assim como avaliar a complexa função do pavimento pélvico.

Por conseguinte, o principal objetivo desta tese foi avaliar os efeitos do TMPP, na prevenção e tratamento da IUE em jovens atletas. Especificamente, este trabalho reuniu os seguintes objetivos:

(i) investigar a prevalência da IUE em atletas e qual a modalidade que mais predispõe a IUE, através de uma revisão sistemática da evidencia científica com meta-análise, que incluiu 9 estudos, com alta qualidade metodológica, registada na base de dados PROSPERO, seguindo as diretrizes do PRISMA (estudo 1);

(ii) investigar o impacto da QV em mulheres desportistas (n=197) com sintomas de IUE, bem como estudar os seus fatores de risco, através de um estudo transversal, utilizando modelos de regressão linear na análise estatística (estudo 2);

(iii) investigar os efeitos de um protocolo de TMPP em atletas de elite com sintomatologia urinária, através de um estudo randomizado controlado, registado no Clinical Trials, (GC=6 e GE=7) (estudo 3);

(iv) estudar a correlação entre a rigidez dos membros inferiores (K_N) / potência (P) e a contração máxima voluntária (CMV) em mulheres desportistas (n=41) através de um estudo preliminar, transversal, inovador, recorrendo a uma plataforma de forças e um perineometro (estudo 4); (v) avaliar as alterações dinâmicas dos MPP em atletas de elite (n=8) através da ecografia translabial 2D e 3D (estudo 5). Os resultados obtidos revelaram: (i) alta prevalência da IUE no voleibol (estudo 1); que a idade, o IMC e os exercícios de alto impacto podem ser fatores promotores de IUE e alterarem a QoL (estudo 2); (iii) já existe alguma indicação de que o TMPP produz melhorias nos resultados da sintomatologia urinária, incluindo a diminuição de perda de urina (estudo 3); (iv) correlação forte entre a P e a CMV, (estudo 4); (v) as atletas dos desportos de alto-impacto tendem a apresentar, ecograficamente, o menor valor de CMV (estudo 5).

Num total de 5 estudos, participaram 1254 atletas nos estudos da revisão sistemática e mais 259 participantes, entre atletas de elite e mulheres desportistas, nos restantes estudos experimentais.

Em suma, o papel da fisioterapia na aplicação de um protocolo de TMPP é imprescindível, bem como na prevenção e tratamento da IUE. Além disso, deve-se considerar uma abordagem multidisciplinar para um estilo de vida mais saudável. Espera-se que esta investigação contribua para o avanço do conhecimento nesta área e apresente recomendações importantes para pesquisas futuras.

KEYWORDS Athletes; High impact exercises; Nulliparous; Pelvic floor Muscles; Physiotherapy; Stress urinary incontinence;

ABSTRACT Scientific evidence has shown a strong association between sports and the prevalence of stress urinary incontinence (SUI). Recent research has shown that SUI affects more and more young athletes and nulliparous women. The practice of high-impact exercise increases intra-abdominal pressure, affecting the structures of the pelvic floor. Additionally, studies show that the quality of life (QoL) of athletes with SUI is often affected, which can lead to the abandonment of sports practice. In view of the above, physiotherapy has a fundamental role in the rehabilitation of the pelvic floor muscles (PFM), being considered the first line of treatment with level A evidence. A protocol for training the pelvic floor muscles (PFMT) stand out in the treatment of this dysfunction. Thus, to make interventions more effective, a more detailed study of SUI in athletes was considered pertinent, addressing the prevalence, risk factors, preventive measures and treatment, as well as assessing the complex function of the pelvic floor.

Therefore, the main objective of this thesis was to evaluate the effects of PFMT in the prevention and treatment of SUI in young athletes. Specifically, this work met the following objectives:

(i) to investigate the prevalence of SUI in athletes whose modality most predisposes to SUI, by means of a systematic review of scientific evidence with meta-analysis, which included 9 studies, with high methodological quality, recorded in the PROSPERO database, following the guidelines of PRISMA (study 1);

(ii) to investigate the impact of QoL in sportswomen (n = 197) with symptoms of SUI, as well as to study their risk factors, via a cross-sectional study, using linear regression models in statistical analysis (study 2);

(iii) to investigate the effects of a PFMT protocol in elite athletes with urinary symptoms, through a randomized controlled study, registered in Clinical Trials, (GC = 6 and GE = 7) (study 3);

(iv) to study the correlation between lower limb stiffness (KN) / power (P) and CMV in sportswomen (n = 41) by means of a preliminary, transversal, innovative study, using a force platform and a perineometer (study 4);

(v) to evaluate the dynamic changes of PFM in elite athletes (n = 8) through 2D and 3D translabial ultrasound (study 5). The results obtained revealed: (i) a high prevalence of SUI in volleyball athletes (study 1); that age, BMI and high-impact exercise can be factors which promote SUI and alter QoL (study 2); (iii) there is already some indication that PFMT produces improvement in the results of urinary symptoms, including decreased urine loss (study 3); (iv) strong correlation between P and maximum voluntary contraction (MVC), (study 4); (v) athletes in high-impact sports tend to have the lowest MVC value on echography (study 5).

In a total of 5 studies, 1,254 athletes participated in the systematic review studies and a further 259 participants, among elite athletes and sportswomen, in the remaining experimental studies.

In short, the role of physiotherapy in the application of a PFMT protocol is essential, as well as in the prevention and treatment of SUI. In addition, a multidisciplinary approach to a healthier lifestyle should be considered. It is hoped that this research will contribute to the advancement of knowledge in this area and present important recommendations for future research.

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List of Abbreviations

2D	Two-dimensional
3D	Three-dimensional
BMI	Body mass index
CG	Control group
EG	Experimental group
ICS	International Continence Society
KHQ	King's Health Questionnaire
K_N	Leg stiffness
MVC	Maximum voluntary contraction
NRCT	Non-randomised controlled trial
P	Power
PA	Physical activity
PFM	Pelvic floor muscles
PFMT	Pelvic floor muscles training
QoL	Quality of Life
RCT	Randomised controlled trial
SD	Standard deviation
SUI	Stress urinary incontinence
UI	Urinary incontinence

INTRODUCTION

Introduction

The International Continence Society (ICS) defines urinary incontinence (UI) as the complaint of any involuntary loss of urine (1) through the urethra, which is objectively demonstrated and constitutes a social and hygienic problem for the person who suffers from it (2). The Portuguese Urological Association indicates 60 million people worldwide with IU, approximately 600,000 in Portugal, mostly women, between 45 and 65 years of age, in the proportion of three women for every man. About 50% of the institutionalized people suffering from urinary incontinence and only 10% of the population does pharmacological treatment, and the rate of cure of stress incontinence is 90% (3). Moreover, the UI is a Public Health problem of high prevalence, rates between 45% and 53% of various types of incontinence in adult women (4).

The UI can be classified as: Stress, Urge and Mixed Urinary Incontinence (5), according to the primary cause of urine loss. Stress urinary incontinence (SUI), the complaint of involuntary loss of urine on physical exertion, sneezing or coughing (1) is the most common type of UI in women, affecting 37% to 42% (6) and most common in pregnant women (7). However, the true prevalence of SUI is still unknown (7). UI, including SUI, is a problem with psychological repercussions in various contexts of life (8-9). Incontinence may negatively impact quality of life (QoL) (10) by causing discomfort, constraint, anxiety, and decreased participation in social activities (11-12). There are several risk factors for SUI, especially: intrinsic, obstetrical and gynaecological factors, and promotional factors (11). Several studies have documented that young women, especially in those practicing high impact sports (13-14), are considered to be at a greater risk of developing this condition (15-17).

SUI affects more and more female athletes and practitioners of physical activity (PA) (12, 15, 18-19). This in athletes is related to how frequently they are subjected to increased intra-abdominal pressure, which is caused by a contraction of the abdominal muscles in high-impact activities without proper awareness and strengthening of the perineal muscle (20). The pelvic floor muscles (PFM) consist of the pelvic and urogenital diaphragm (11) and contribute to the continence mechanism by contractions which are rapid, strong and reflexive (21-22). This function is “the ability to contract and relax the PFM voluntary and involuntary” (23).

At present, conservative management is the first-line treatment because of its effectiveness and lack of adverse effects (24-25). This treatment consists of lifestyle changes, anti-incontinence devices usage, incontinence prevention or containment products, complementary or alternative measures, but above all, physiotherapy. It can be divided into: (i) biofeedback (digital, visual, vaginal cones); (ii) electrical stimulation; (iii) PFM exercises

(26). These consist of a pelvic floor muscles training (PFMT) protocol which is the most recommended conservative treatment (13, 16, 25, 27-28). The PFMT can be a protective factor and is very important that every woman learns how to perform maximum voluntary contractions (MVC) to prevent SUI (21).

As a result, PFMT protocol can be effective in SUI. A great deal of studies have concluded that PFMT is an effective therapy for SUI (24, 28-30). However, evidence supporting this type of intervention is still limited in Portugal. There are a few randomized controlled trials (RCT) which have studied the effectiveness of PFMT intervention in improving urinary symptoms in elite female athletes. Another critical component of SUI is the lack of information for athletes, who are unaware of the risks of UI and find urine loss normal. On the other hand, PFMT protocols are not addressed by the professionals who accompany them. (11, 31-32). However, previous studies assessing the SUI can be a barrier to women's participation in sport and fitness activities and, therefore, it may be a threat to women's health, self-esteem and well-being (11, 16). The costs associated with the addition of PFMT are relatively small, and the time needed by the physiotherapist to provide support is approximately 20 minutes/training. Hence, this intervention can be implemented in various women's teams, without the need for significant additional costs or human resources and SUI may no longer be an obstacle for these athletes. Further research is needed to study the cost-effectiveness of this PFMT protocol. Consequently, the hypothesis of changing one's lifestyle after the intervention translates into better measures related to improving quality of life (10). Future research should apply a PFMT protocol.

This thesis focuses on understanding whether PFMT protocol can support athletes with SUI in their disorder management and impact significantly on their QoL. Specifically, it aimed to: i) gain more insight on the role of the physiotherapist's intervention to reduce the frequency of urine exacerbations and improve health-related outcomes; and ii) investigate the impact of QoL on athletes, focused behaviour intervention combined with PA levels, and PFMT.

The work developed to accomplish these aims is presented in seven chapters. After the introduction (briefly outlining the impact of QoL in female athletes with SUI), we have Chapter 1 (Background), an overview of the main challenges in high impact exercise, and SUI is presented along with a description of the athletes' problems. Chapter 2 includes a systematic review which provides an update of knowledge regarding the prevalence of SUI in female athletes. Chapters 3, 4, 5, and 6 compile the original studies developed within the scope of this thesis. Chapter 3 compiles a cross-sectional study, assesses PFM in sportswomen, QoL, and related factors. Chapter 4 is an RCT which includes the effects of PFMT Protocol on elite female nulliparous volleyball athletes. Chapter 5 compiles another cross-sectional study, explores muscle power and leg stiffness, comparing with MVC values via perineometry. Chapter 6 include one prospective comparative study, the aim was to characterize PFM function in elite nulliparous athletes, using translabial two-dimensional/three-dimensional (2D/3D) ultrasound. The main findings of the studies presented in Chapters 2-6 are integrated and discussed in Chapter 7. Finally, presents the main conclusions and recommendations for future research and clinical practice.

The illustrative scheme of the various studies is shown in Figure 1.

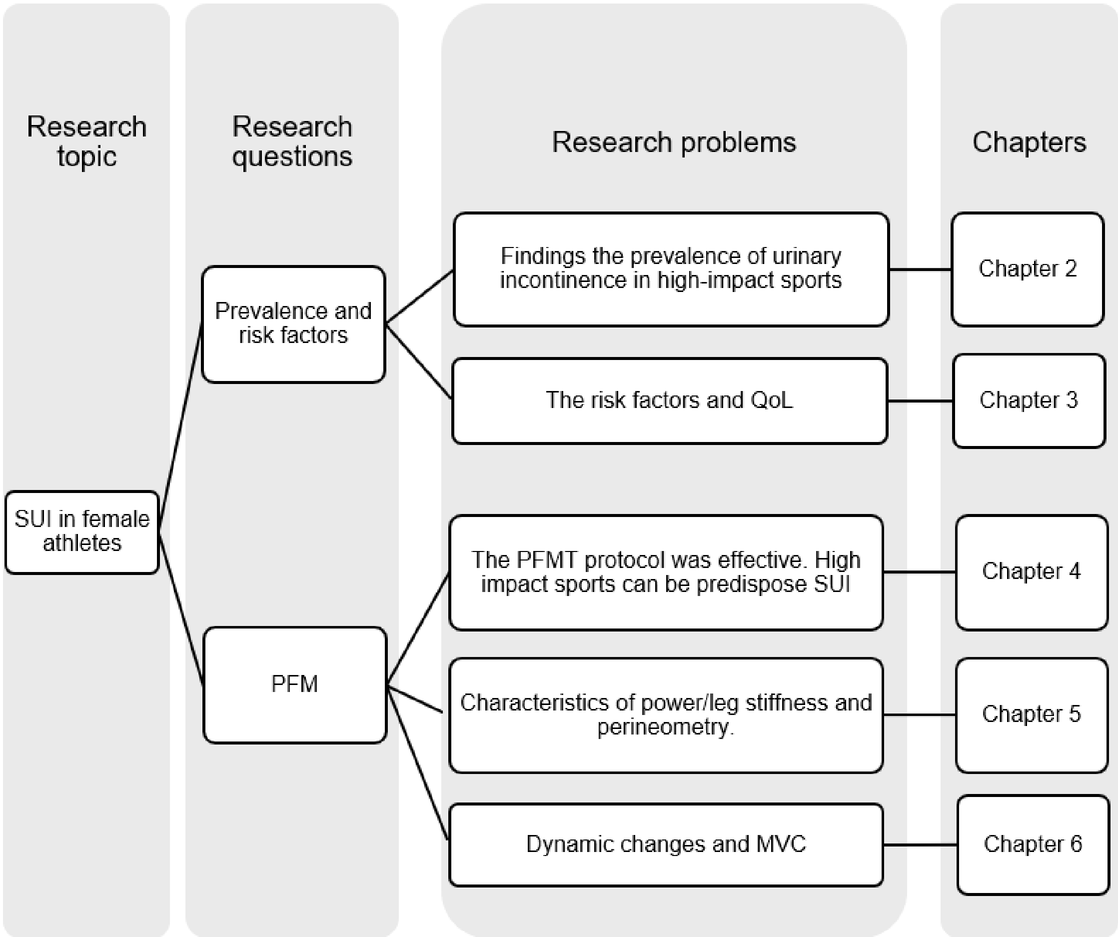

Figure 1 - Schematic diagram of the rationale for the structure of the thesis.

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CHAPTER 1 – BACKGROUND

Background

This chapter provides a definition of SUI, describes the impact on QoL, highlights the importance of promoting an active lifestyle in athletes with SUI, implementing a PFMT protocol, and dynamic changes in PFM. Then, an overview of the literature regarding interventions in SUI is presented along with a description of the problems and solutions for these.

Stress Urinary Incontinence definition and global burden

The International Continence Society (ICS) defined SUI as the complaint of involuntary loss of urine on effort or physical exertion or sneezing or coughing (1). SUI is characterized by loss of urine when intravesical pressure exceeds maximum urethral pressure in the absence of detrusor muscle contraction (2). It is the most common type of incontinence among women, thus representing a major social and psychological problem (3). SUI is the type of loss that predominantly affects younger women (4-5). Although there is evidence that UI preferentially affects postmenopausal and multiparous women and recent studies show that there is a high prevalence of SUI among female athletes (6-7). Currently, it is known that the aetiology of UI is multifactorial and that among the predisposing factors are hormonal status, advancing age, obesity, number of pregnancies and parity, and the highest risk occurs in women with more than four deliveries, new-borns with 4 kg or more, trauma during childbirth, genetic differences in connective tissue, neuromuscular trauma of the PFM, and deficient or inadequate function of these muscles (8).

The SUI is usually assessed in studies by means of self-completion questionnaires and in turn the loss of urine is quantified through the pad test. However, a complete assessment must obey primary and secondary measures. The primary measures are: (i) initial clinical evaluation (history, physical examination, PFM evaluation, urine analysis, residual urine, urethrocytoscopy, blood tests and imaging, including pelvic floor ultrasound scans); (ii) QoL measurements; (iii) voiding diary (a record of the number of urinations as well as voiding volumes, the height of each urination during the day and night for at least 24 hours); (iv) stress testing (checking the external urethral meatus during coughs for urine leakage); (v) pad test (quantifies urine loss); (vi) urethral mobility (swab test, perineal ultrasound and videocystourethrography). Secondary measures are: (i) urodynamic tests (bladder and urethral function, uroflowmetry and post-urination residual volume, cystometry, pressure /

flow study, urethral pressure profilometry, loss and prolapse pressures); (ii) neurophysiological tests (8).

Impact on Quality of Life

In women, UI is a major health problem and has a negative impact on QoL (9). Population studies from numerous countries have reported that the prevalence of UI ranged from approximately 5% to 70%, with most studies reporting a prevalence of any UI in the range of 25-45% (10). UI is considered a major public health problem and if it is prolonged without medical intervention, it can get worse and have even more adverse consequences on women's health (8). In addition, the loss of urine negatively influences women's self-esteem and QoL, which can lead to feelings of embarrassment and anxiety, as well as a reduction in their participation in sports and social activities (4, 11). There may be changes in the athlete's performance, as well as some women even stopping attending the gym. They are not in the habit of asking their personal trainer, family doctor or any professional accompanying them for help, as they find urine loss normal or for some UI is still seen as a taboo (11).

Pelvic Floor Muscles training in Stress Urinary Incontinence

Several studies have documented that young women, especially those practicing high impact sports carry a high risk to develop SUI (6, 12-14). SUI in athletes is related to how frequently the athletes are subjected to increased intra-abdominal pressure, which is caused by a contraction of the abdominal muscles in high-impact activities without proper awareness and strengthening of the perineal muscles (15-17). Strenuous PA that involves intra-abdominal pressure can overload and chronically damage the perineum (including the periurethral striated muscle), decreasing the contraction strength of the PFM and increasing the risk for SUI (12, 16, 18-19). Another justification is muscle fatigue, during PA type II fibres are recruited, which have a low capacity for maintaining the muscle tone of the PFM, one of the facts that can compromise the UI mechanism (20), since this mechanism of continence demand complex coordination of PFM, urethra, bladder, and supporting ligaments (21-22).

It is necessary to emphasize that when we talk about PA, we refer to it as any bodily movement produced by skeletal muscles which substantially increases energy expenditure (23). PA and exercise are often used interchangeably, however, these terms are not synonymous. Exercise is a subcategory of PA which is planned, structured and repetitive, and aims to improve and/or maintain physical fitness. The intensity of PA is commonly classified as light, moderate or vigorous, depending on the energy expenditure associated with it. Other parameters, such as the number of daily steps, may also be considered when assessing PA (24). Exercises can be classified according to the type and intensity of the exercise performed and regarding the danger of bodily injury from collision, as well as the consequences of syncope. Each sport is categorized by the level of intensity (low, medium, high). In high impact exercises, the practitioner's feet are, at some point, out of touch with the ground, like jogging, running, and jumping (25).

The mechanism of continence includes striated (voluntary control) and smooth (involuntary) muscles. Striated muscles adapt to the requirements of training programs based on the principles of exercise physiology: specificity, overload, and reversibility. The increase in strength in the first 6 to 8 weeks is predominantly neural (frequency of activation and recruitment of motor units). Hypertrophy may also begin between 6 and 8 weeks and may last for years. It is generalized to all fibres, however, the potential for hypertrophy is greater in fast than slow fibres. The PFMT alters muscle morphology by increasing sectional area, modifies neuromuscular function by increasing the ability to recruit additional motor units and the frequency of arousal, and improves muscle tone and viscoelastic properties of connective tissue. PFMT is a progressive training of specificity, intensity, rest time, frequency, volume, and duration (8, 15, 22).

Therefore, interventions coupling PA and PFMT may have the potential to promote behaviour change and empower lifestyle modification in athletes with SUI (26). This is a promising area for future research.

Pelvic Floor Muscles and Dynamic Changes

The PFM consist of the pelvic and urogenital diaphragm (15) and contribute to the continence mechanism by contractions that are rapid, strong, and reflexive (27-28). This function is “the ability to contract and relax the PFM voluntary and involuntary” (29).

Female pelvic organs are grouped into anterior (bladder and urethra), central (vagina and uterus), and posterior (or anorectal) compartments. The spectrum of pelvic floor dysfunction depends on the compartment involved, and includes UI, constipation, and pelvic organ prolapse (POP), occurring in varying combinations (30-31). The position and mobility of the structures of the anterior compartment are important to the study of UI (8, 30). Loss of anterior vaginal support may result in urethral hypermobility, cystocele or anterior vaginal wall prolapse. The pubovesical, the pubourethral, and the uterosacral-cardinal muscles complex uphold the vesical and vaginal positions, as they stabilize the distal urethra, and maintain the cervix and the bladder base attached to the connective tissue of the fascia in the pelvic bones (30, 32). Damage or degradation of these apical supports is common in women with SUI and vaginal prolapse (33). The normal position of the rectum is also maintained by the rectal fascia and the levator ani musculature (34). Increased pressure in the proximal portion of the anal canal is supported by the puborectal muscle through vigorous contraction. To strengthen this effect, the iliococcygeal muscle firms the levator plate and the lateral ligaments of the rectum (30). Whilst physical examination, standardized questionnaires and imaging studies are the usual tools to assess pelvic floor dysfunction, computer simulation (biomechanical models) may also be used to learn and predict the biomechanical behaviour of the pelvic structures under stress or after damage (22, 30, 35).

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CHAPTER 2 – PREVALENCE OF URINARY INCONTINENCE IN HIGH-IMPACT SPORT ATHLETES: A SYSTEMATIC REVIEW AND META-ANALYSIS

Pires, T., Pires, P., Moreira, H., Viana, R. (accepted). Prevalence of urinary incontinence in high-impact sport athletes: a systematic review and meta-analysis. *Journal of Human Kinetics*.

Abstract

The aim of this study was to systematize the scientific evidence that assessed the prevalence of urinary incontinence in female athletes and determine which modality is most predisposed to stress urinary incontinence. From September to December 2018, a systematic literature search of current interventional studies of stress urinary incontinence of the last ten years was performed using PubMed, EMBASE, Scopus and Web of Science databases. The methodological quality was assessed by the Downs and Black scale, while the data collected from the studies were analyzed through meta-analysis. Nine studies met the eligibility criteria, meaning they included reports of urinary incontinence in different sports. The meta-analysis showed 25.9% prevalence of urinary incontinence in female athletes in different sports, as well as 20.7% prevalence of stress urinary incontinence. The most prevalent high impact sport was volleyball, with the value of 75.6%. The prevalence of urinary incontinence can be high in female athletes, with high-impact sports potentially increasing the risk for stress urinary incontinence. Further research is needed regarding the potential risk factors related to the onset of urinary incontinence.

Keywords: Exercise, female athletes, pelvic floor muscle, stress urinary incontinence.

Review Criteria

PubMed, EMBASE, Scopus and Web of Science databases were searched (from September to December of 2018, updated until July 2019) for randomised and non-randomised controlled trials evaluating the prevalence of urinary incontinence in high-impact sport athletes. Meta-analyses were performed, when appropriate.

Message for the Clinic

Urinary incontinence is a public health problem that primarily, affects women. Its prevalence rate is high in athletes who practice high impact exercises. The studies included in this review provided evidence for the efficacy of the PFMT protocol at SUI. However, to advocate the use of PFMT as an athlete management approach and incorporate it into practice, further work needs to be conducted, respectively the RCTs.

Introduction

The International Continence Society (ICS) and the International Urogynecological Association (IUGA) define urinary incontinence (UI) as a symptom, namely the complaint of any involuntary leakage of urine (Haylen et al., 2010). The most frequent form of UI in women is stress urinary incontinence (SUI) which appears to be a common problem in the last decade among nulliparous young women (Da Roza et al., 2015b; Da Roza et al., 2012). The mean prevalence in various studies is 30% among middle-aged women, reaching 47% in women who exercise regularly (Thomaz et al., 2017), having a significant impact on their quality of life (Abrams et al., 2010; Maia et al., 2015; Viana et al., 2015). SUI may be a barrier to women's participation in sport and fitness activities. Therefore, it may be a threat to women's health, self-esteem and well-being (Bø, 2004; Viana et al., 2015).

Several studies have documented that young women, especially those practicing high impact sports, are considered to be at greater risk for developing SUI (Hagovska et al., 2017; Leitner et al., 2016). SUI in athletes is related to how frequently athletes are subjected to increased intra-abdominal pressure, which is caused by a contraction of the abdominal muscles in high-impact activities without proper awareness and strengthening of the perineal muscles (Bø, 2004; Borin et al., 2013; Teixeira et al., 2018). Strenuous physical activity that involves intra-abdominal pressure can overload and chronically damage the perineum (including the periurethral striated muscle), thus decreasing the contraction strength of the pelvic floor muscle (PFM) and increasing the risk for SUI (Borin et al., 2013; Da Roza et al., 2015b; Reis et al., 2011). Another factor is muscle fatigue, which occurs during physical activity when type II fibers are recruited. These fibers have a low capacity for maintaining the muscle tone of the PFM, one of the factors that can compromise the UI mechanism (Reis et al., 2011; Teixeira et al., 2018; Thomaz et al., 2017). This can adversely affect the quality of life causing embarrassment, anxiety and reduced participation in social activities (Da Roza et al., 2012; Viana et al., 2015). Therefore, it is important to establish a complete diagnosis, through questionnaires on the quality of life and urine quantification tests (Jeyaseelan et al., 2000). Numerous studies have concluded that pelvic floor muscle training (PFMT) is an effective therapy for SUI (Ferreira et al., 2014; Leitner et al., 2019; Oliveira et al., 2017; Sousa et al., 2015).

The aim of this study was to systematize the scientific evidence that assessed the prevalence of UI in female athletes and determine which modality is most predisposed to SUI.

Methods

This systematic review was registered in the PROSPERO database (CRD42019116085) (www.crd.york.ac.uk/prospero), and followed the recommendations of the PRISMA guidelines (Moher et al., 2015).

Search strategy and eligibility criteria

To identify relevant articles, a bibliographic search was carried out in four electronic databases, i.e., PubMed, EMBASE, Scopus and Web of Science, between September and December of 2018. The search used the following filters: ”humans”, “English and Portuguese language” and ”10 years” and the following keywords: “High-impact” OR “Sport” (MeSH) OR “Exercises” (MeSH) AND “Female athletes” (MeSH) AND “Pelvic Floor Muscle” AND “Stress urinary incontinence” (MeSH). This specific research period was selected due to a notable increase in the scientific literature investigating the prevalence of SUI in high-impact sports in the last decade. Nine hundred thirty potentially relevant articles were found. The study selection flow chart is shown in Figure 3.1. These studies are quasi-experimental and observational. They involved athletes with UI symptoms, with the mean age between 18 and 45 years. The exclusion criteria were studies including participants who had had previous pelvic surgery, the elderly, women in their menopause, pregnant and parous women who were at least 12 months postpartum, other reviews or meta-analysis, and case studies.

Quality assessment

The methodological quality assessment was performed independently by two reviewers (TP and RV), using the Downs and Black scale (Downs and Black, 1998) for randomized and non-randomized studies. There were 27 items that assessed domains reporting, the external validity, study bias, confounding/selection bias and power of the study. For the assessment of the observational studies, an adaptation was performed, as suggested by the Cochrane Library, excluding items related to experimental studies and Cohort and case-control studies [4, 7, 8, 13, 14, 15, 17, 19, 21-24, 27] because they did not fit the methodological design of the analyzed studies (Table 3.1). In this systematic review, studies were classified as having high methodological quality when they presented scores ≥ 70% on the scale (19 points for a randomized controlled trial, 10 points for case control and cohort studies, 9 points for observational studies and 8 points for cross-sectional studies). Any disagreement between the reviewers was resolved by consensus.

Statistical Analysis

Despite the heterogeneity in the design and sample size of the nine studies analyzed, it was possible to carry out a meta-analysis. A descriptive analysis of the studies included in the systematic review was also performed. A generalised linear mixed model (GLMM) – more specifically, a random intercept logistic regression model – was used for the meta-analysis of the proportions of UI and SUI. The meta-analysis was performed using the *Package meta* (Schwarzer, 2007), available for program R (Team, 2016). The heterogeneity was evaluated with the Cochran's Q Test and the I^2 statistic of Higgins and Thompson. The Cochran's Q test evaluates the null hypothesis of the existence of homogeneity between the samples, with the studies being considered homogeneous if this hypothesis is not rejected, that is, if $p > 0.05$, with a level of significance of 5%. The I^2 statistic of Higgins and Thompson ranges from 0% (negative values are adjusted to 0%) to 100%, being 0% indicative of absence of heterogeneity. Higgins et al. (2003) proposed to classify the heterogeneity as low for values close to 25%, moderate for values close to 50% and high for values near or greater than 75%.

Results

Study Selection

The search strategy yielded 930 potentially relevant studies of which 454 duplicate records were removed. A selection process based on titles and abstracts led to the exclusion of 303 studies. After applying the inclusion and exclusion criteria, 174 studies were excluded, and 71 studies entered the full-text review. From those, 38 were excluded, with the reasons for exclusion being presented in the PRISMA flowchart. In total, 9 studies were included (Figure 1).

Study Characteristics

Study characteristics are presented in Table 1 Most studies were cross-sectional (n = 6), with a prospective/observational design (n = 1), an experimental study (n = 1) and a non-randomized controlled trial (n = 1). The systematic review identified nine studies conducted between 2010 and 2018. They included a total sample of 1254 participants, with an average age of 22.8 (±6.1) years. Nine studies included the prevalence of UI, with 8 including the prevalence of SUI.

Table 1

Study characteristics

Study	Sample	Study design	Age in years, mean (SD)	Assessment	Intervention	Results	Quality Score (Down and Black)
Borin et al., 2013	N = 40 Volleyball (n=10) Handball (n=10) Basketball (n=10) Nonathletes (n=10)	Prospective Observational	24.0 (8.48)	Perineometer	Volleyball Handball Basketball	Volleyball 20% Handball 20% Basketball 10% Nonathletes 0%	7
Da Roza et al., 2015a	N = 386 Nulliparous athletes	Cross-sectional	21.4 (2.5)	ICIQ-SF	1^{st}, 2^{nd}, 3^{rd} and 4^{th} quartile (0-30, 31-180, 181-420, 421-2940 min of exercise/week)	SUI 49.4% UUI 22.1% MUI 28.6%	10
Da Roza et al., 2015b	N = 22 Nulliparous / trampolinists	Cross-sectional	18.1 (3.4)	ICIQ-SF Questionnaire	1^{st}, 2^{nd} and 3^{rd} tertiles	SUI 72.7%	11
Ferreira et al., 2014	N = 32 (Nulliparous / volleyball) Intervention (n=16) Control (n=16)	Experimental study	Intervention 19.4 (3.24) Control 19.1 (2.11)	Questionnaire Pad-test Frequency of urine leakage (7-day diary before and after PFMRP)	3-months PFMRP	Intervention 100% Control 100%	8
Hagovska et al., 2017	N = 503 Nulliparous / High-impact exercises	Cross-sectional	21.1 (3.6)	ICIQ-SF OAB-q I-QOL IPAQ-SF	Low MET (3.3) <600 Moderate MET (4.0) 600-1500 High MET ≥3000	SUI 13.52% UUI 0.80%	10
Jácome et al., 2011	N = 106 Athletics (track and field) (n=32) Basketball (n=36) Indoor football (n=38)	Cross-sectional	Athletics 20.0 (1.8) Basketball 23.7 (4.0) Indoor football 24.0 (4.8)	Questionnaire	Track and field, basketball and indoor football	SUI 61.4% UUI 20.5% MUI 18.2%	9
Leitner et al., 2017	N = 50 (running) Continent (n=28) SUI (n=22)	Cross-sectional and exploratory study	Continent 38.7 (10.0) SUI 45.3 (9.5)	Surface eletromyographic Tripolar vaginal probe	Running on a treadmill	No differences between continen and incontinent	10
Póswiata et al., 2014	N = 112 Cross-country skiers (n=57) Runners (n=55)	Cross-sectional	Cross-country skiers 26.61(4.41) Runners 29.49 (6.02)	Questionnaire UDI-6	Cross-country skiers and Running	SUI 45.54%	8
Rivalta et al., 2010	N = 3 Nulliparous / volleyball	NRCT	30.6	Vaginal probe Urogynecologic evaluation Puborectalis test	Volleyball PFMRP	SUI 0%	8

Note. ICIQ-SF International Consultation on Incontinence Questionnaire-Short Form, IPAQ-SF International Physical Activity Questionnaire-Short Form, I-QOL Urinary Incontinence Quality of Life Scale, MET Metabolic Equivalent, MUI Mixed Urinary Incontinence, OAB-q Overactive Bladder Questionnaire, PFMRP Pelvic floor muscle rehabilitation program, SUI Stress Uriary Incontinence, UDI-6 Urogenital Distress Inventory, UUI Urgency Urinary Incontinence.

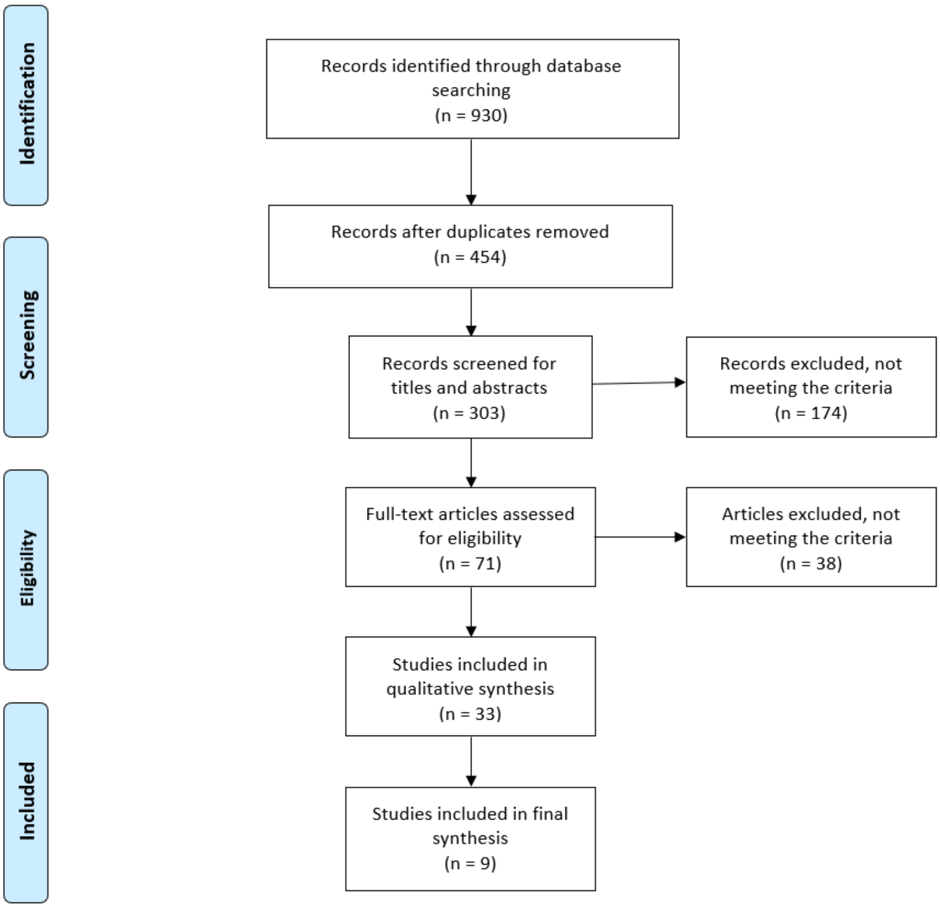

Figure 1. Flow diagram for study selection**.**

Table 2

Assessment of the quality of the studies

Reference	Reporting	External validity	Bias	Selection variable (Confounding and Power)	Final score
Borin et al., 2013	5	0	2	0	**7**
Da Roza et al., 2015a	6	0	3	1	**10**
Da Roza et al., 2015b	6	0	3	2	**11**
Ferreira et al., 2014	5	0	2	1	**8**
Hagovska et al., 2017	5	0	2	1	**8**
Jácome et al., 2011	5	0	3	0	**8**
Leitner et al., 2017	5	0	3	2	**10**
Póswiata et al., 2014	5	0	2	1	**8**
Rivalta et al., 2010	5	0	1	2	**8**

Note. The values refer to the score of the studies on certain domains (sub-scales) of the adapted Downs and Black Scale

Prevalence of Urinary Incontinence

The prevalence of the studies included in the meta-analysis was 25.9% (95% confidence interval (CI): 23.5 - 28.3%). The Cochran's Q test and the I^2 statistic by Higgins et al., (2003) show the existence of high heterogeneity in the prevalence of studies included in the meta-analysis: $Q(8) = 110.73$; $p < 0.001$; $I^2 = 92.8\%$ (Figure 2).

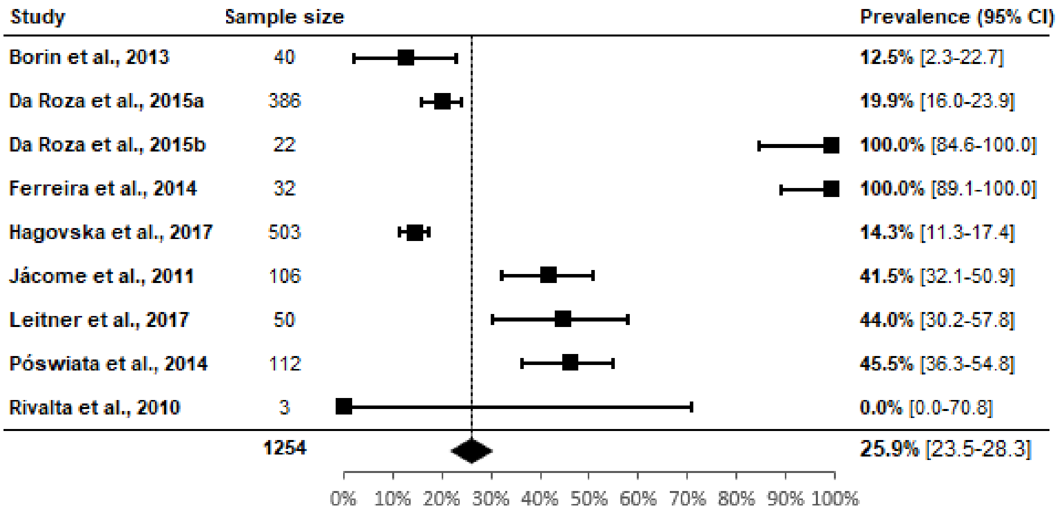

Figure 2 - Prevalence of urinary incontinence in female athletes

(Test of heterogeneity: $Q(8) = 110.73$; $p < 0.001$; $I^2 = 92.8\%$ [88.5%; 95.5%])

Prevalence of Stress Urinary Incontinence

The prevalence of studies included in the meta-analysis was 20.7% (95% (CI): 18.5% - 22.9%). The Cochran's Q test and the I^2 statistic by Higgins et al., (2003) show the existence of high heterogeneity in the prevalence of studies included in the meta-analysis: $Q(7) = 135.67$; $p < 0.001$; $I^2 = 94.8\%$ (91.9%; 96.7%) (Figure 3).

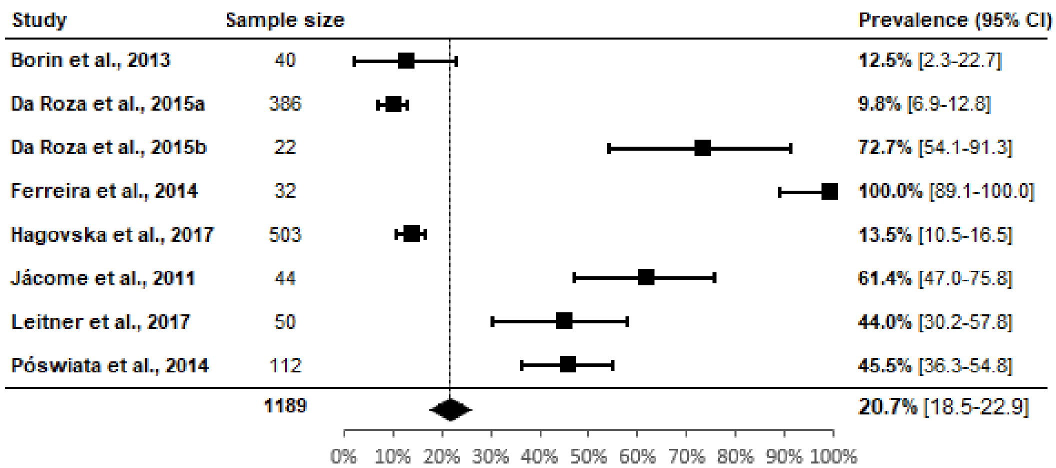

Figure 3 - Prevalence of stress urinary incontinence in female athletes.

(Test of heterogeneity: $Q(7) = 166.787$; $p < 0.001$; $I^2 = 95.8\%$ [93.6%; 97.3%])

Prevalence of Sports

The prevalence of high-impact sports ranged from 14.3 to 75.6% (volleyball). The prevalence of studies included in the meta-analysis was 25.6% (95% (CI): 23.5% - 28.1%). The Cochran's Q test and the I^2 statistic by Higgins et al., (2003) show the existence of high heterogeneity in the prevalence of studies included in the meta-analysis: Q(8) = 138.00; $p < 0.001$; I^2 = 94.2% (91.0%; 96.3%) (Figure 4).

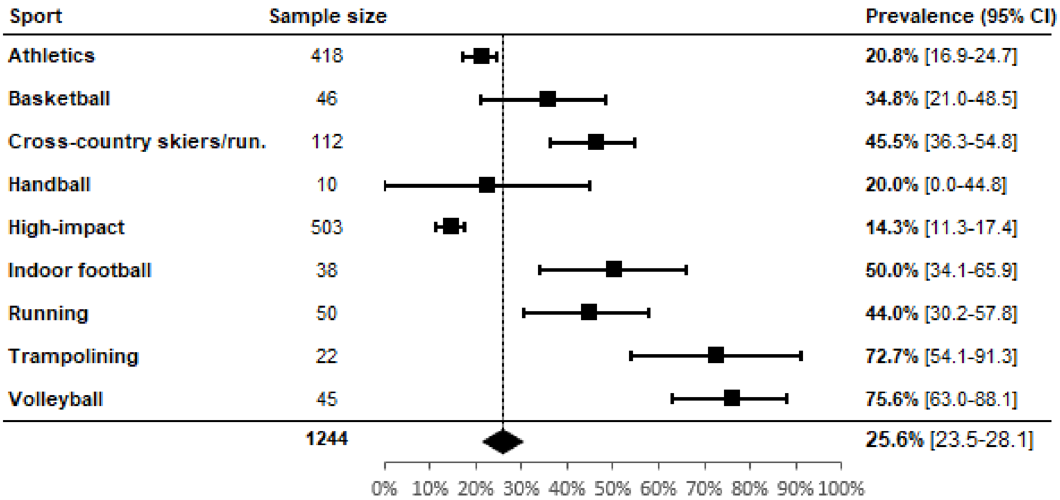

Figure 4 - Prevalence of urinary incontinence in high-impact sports.
(Test of heterogeneity: Q(8) = 138.00; p < 0.001; I^2 = 94.2% [91.0%; 96.3%])

Discussion

UI is considered the most common PFM dysfunction in female athletes, affecting 15 to 17% of women every day (Dieter et al., 2015; Teixeira et al., 2018) and SUI is considered the most common type of UI (Dieter et al., 2015; Goldstick and Constantini, 2014; Maia et al., 2015). This systematic review and meta-analysis found that the prevalence of UI among female athletes was 25.9% and when SUI was analysed separately, the prevalence was 20.7%. The prevalence in high impact sports was 25.6%, with the highest prevalence observed in volleyball, reaching the value of 75.6%. Several studies have also found high prevalence of UI among female athletes (Almousa and Van Loon, 2017; Lourenco et al., 2018; Santos et al., 2018; Teixeira et al., 2018). There is a strong relationship between physical activity and SUI (Goldstick and Constantini, 2014; Hagovska et al., 2017; Teixeira et al., 2018). A possible justification for these higher rates is that intense physical activity promotes an increase in intra-abdominal pressure and the repetitive increases may lead to weakness and stretching of the PFM and, consequently, to UI (Lourenco et al., 2018; Maia et al., 2015; Santos et al., 2018). This increase in abdominal pressure results in morphologic and functional modifications, such as deformation of ligaments and connective tissue (Da Roza et al., 2015b; Fozzatti et al., 2012; Kruger et al., 2007; Lourenco et al., 2018). This is believed to be the cause of urinary dysfunctions in young and nulliparous women who have no other risk factor when they reach PFM pressure threshold (Lourenco et al., 2018; Nygaard et al., 2012).

However, several studies have also shown that intense physical activity could strengthen the PFM through the co-contraction between them and the abdominal muscles (Bø, 2004; Santos et al., 2018). Some studies used tests involving high impact exercise (running and jumping) before and after treatment, and showed that it is possible to cure or reduce UI during physical activity (Bø, 2004; Junginger et al., 2014; Mørkved et al., 2002; Santos et al., 2018) and to delay or avoid surgery (Bø and Hilde, 2013).

Female athletes report high prevalence of UI in high-impact sports (Almousa and Van Loon, 2017; Bø and Borgen, 2001; Eliasson et al., 2002; Santos et al., 2018). High impact activities were defined as those involving the performance of several jumps and actions related to maximum abdominal contractions; these increase intra-abdominal pressure and exert an impact force directly on the PFM (Bø, 2004; Casey and Temme, 2017; Reis et al., 2011; Santos et al., 2018; Teixeira et al., 2018). Thus, we have classified all sports which involve jumping and running as high impact (Carvalhais et al., 2018; Mitchell et al., 2005). For high impact exercises, this review presents a new record in the prevalence of UI, showing a prevalence in volleyball of 75.6%. The other sports showed the following prevalence: 72.7% for trampolining, 50% for indoor soccer, 45.5% for cross-country skiers and runners, 44% for running, 34.8% for basketball, 20.8% for athletics, and 20% for handball. Until now, several studies have pointed at jumping and trampolining as having the highest prevalence of UI in high impact sports. Some authors corroborate that the prevalence of UI ranges from 28% to 80%, with the highest prevalence in high impact female athletes, such as trampolinists, gymnasts, hockey players, and ballet dancers (Carls, 2007; Goldstick and Constantini, 2014; Simeone et al., 2010). Jumping is the activity that is most likely to provoke UI. Corroborating this review, Reis et al., (Reis et al., 2011) found 50% prevalence of SUI in basketball players and 30% in volleyball players, classifying these sports as being at a high risk for UI. Other authors report more athletes experience leakage during training rather than competition (95.2% vs. 51.2%), possibly because of higher catecholamine levels during competition which act on the urethral α-receptors to maintain its closure (Goldstick and Constantini, 2014; Thyssen et al., 2002). A 40% prevalence was found among all high impact sports, which included team sports, track and field, and aerobics; Eliasson et al., (Eliasson et al., 2002) found an 80% prevalence of UI among trampoline athletes and

Almeida and Machado (Almeida and Machado, 2017) found that 37.5% of women who practiced jumps (an aerobic activity with repeated jumping) reported that they had experienced UI.

This systematic review and meta-analysis demonstrate that the prevalence of UI could be high in female athletes and that high impact sports can increase the risk for UI. SUI may be a barrier to women's participation in sport and fitness activities and, consequently, decrease the quality of life of athletes. This systematic review also confirmed that volleyball (a high impact sport) was the sport with the highest prevalence of SUI. Understanding the effect of the risk factor mechanisms on the PFM will enable us to implement preventive strategies and advise appropriately on the prevention of UI. It is especially important to sensitize all the professionals (physiotherapists, coaches, fitness instructors, and sports doctors) involved to timely detect or prevent SUI.

The limitation of the study is in fact the variability of outcome measures and the heterogeneity of the study designs. Some studies used one single measure as the main outcome, while other studies combined several. In some studies, only the questionnaire was used to assess the prevalence of SUI symptoms. It correlates very well with urodynamic tests or other urogenital diagnostic (e.g. pad test, voiding diaries). Further clinical studies should be performed to analyse the prevalence of UI, including more reliable diagnostics.

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CHAPTER 3 – ASSESSMENT OF PELVIC FLOOR MUSCLES IN SPORTSWOMEN: QUALITY OF LIFE AND RELATED FACTORS

Pires, T., Pires, P., Moreira, H., Gabriel, R., Viana, S. Viana, R. (2020). Assessment of pelvic floor muscles in sportswomen: quality of life and related factors. *Journal of Physical Therapy in Sport.*

Abstract

Objectives: To evaluate maximum voluntary contraction (MVC) of the pelvic floor muscles (PFM) in sportswomen, to observe the urinary symptoms and their impact on the quality of life (QoL).

Design: Observational cross-sectional study.

Setting: Gyms and teams in the North of Portugal.

Participants: Sportswomen (n=197)

Main outcome measures: The measurement was performed using a manometer. The sportswomen were instructed to perform 3 MVC of the perineum, held for 3 s. The Kings Health Questionnaire (KHQ) was used to evaluate urinary symptoms and the QoL of the sportswomen.

Results: Age significantly influenced ($p < 0.05$) the QoL in all domains. An increase in BMI was also significantly associated with a decrease in the QoL. MVC values had a highly significant effect on the overall QoL and all domains, including a reduction in urinary symptoms. The weekly time of physical activity was associated with a better QoL in symptomatology. The practice of high-impact activities decreased the QoL (compared to low-impact activities). The vaginal resting pressure values ranged from 1.60 to 59.80 (24.34 ± 11.00).

Conclusions: Age, BMI and high-impact sports appear to be the leading factors that promote the onset of stress urinary incontinence (SUI), which in turn decrease the QoL in sportswomen. There was a positive association between MVC and weekly time of physical activity in the QoL.

Keywords Maximum voluntary contractions, physical activity, sports athletes, stress urinary incontinence.

Highlights

- Age, BMI and high-impact sports appear to be the leading factors leading to the onset of stress urinary incontinence, which in turn decrease the quality of life in sportswomen.
- The weekly time of physical activity is associated with a better quality of life.
- Increased maximum voluntary contraction values lead to fewer urinary symptoms.

- The practice of high-impact activities decreases the quality of life (compared to low-impact activities).

Abbreviations

KHQ - King's Health Questionnaire
MVC – Maximum Voluntary Contractions
PFM - Pelvic Floor Muscles
PFMT - Pelvic Floor Muscles Training
QoL – Quality of Life
SUI - Stress Urinary Incontinence
UI - Urinary Incontinence
VRP – Vaginal Resting Pressure

1. Introduction

Urinary incontinence (UI) is worldwide a Public Health problem (1) and a social problem affecting up to 50% of women (2-3). Stress urinary incontinence (SUI) is the most frequent form of UI. The International Continence Society (ICS) and the International Urogynecological Association (IUGA) define SUI as the complaint of involuntary loss of urine on effort or physical exertion or sneezing or coughing (1).

There are several risk factors for SUI, especially: intrinsic (Race, family predisposition, anatomical or neurological abnormalities), obstetrical and gynaecological factors (Pregnancy, childbirth and parity; side effects of pelvic surgery and radiotherapy; Genital prolapse) and promotional factors (Age, comorbidities, obesity, constipation, smoking, occupational activities, urinary tract infections, menopause, medication) (4). In this study we evaluated some promotional risks such as age, obesity (BMI) and occupational activities (high-impact exercises). In the last decade, several studies have documented that young women, especially in those practicing high impact sports (volleyball players and trampolinists have a rate from 65.7 to 80%) (5-6) are considered to be at greater risk for developing (2-3, 7). SUI affects more and more female athletes and practitioners of physical activity (2, 8-10). This in athletes is related to how frequently the athletes are subjected to increased intra-abdominal pressure, which is caused by a contraction of the abdominal muscles in high-impact activities without proper awareness and strengthening of the perineal muscle (11). These high impact activities can be classified according to the type and intensity of exercise performed and with regard to the danger of bodily injury from collision, as well as the consequences of syncope. Each sport is categorized by the level of intensity (low, medium, high). In high impact exercises, the practitioner's feet are at some point both off the ground, as in jogging, running, and jumping sports (12).

The pelvic floor muscles (PFM) consists of the pelvic and urogenital diaphragm (4) and contribute to the continence mechanism by contractions that are rapid, strong and reflexive (13-14). This function is “the ability to contract and relax the PFM voluntary and involuntary” (15). Pelvic floor muscle training (PFMT) can be a protective factor, which is very important that every woman learns how to perform maximum voluntary contractions (MVC) to prevent SUI. This can adversely affect the quality of life (QoL) by causing embarrassment, anxiety, impact on work performance, negative feelings, interference of sexual life and reduced participation in social activities (7). A lot of studies have concluded that PFMT is an effective therapy for SUI (16-19). The aim of this study was to evaluate MVC of the PFM in female athletes and verify the urinary symptoms and its impact on the QoL and to analyze whether urinary symptoms is influenced by the volume of physical activity performed or by the intensity of the sport.

2. Methods

2.1 Design

This is an observational cross-sectional study of Portuguese sportswomen, carried out between February and May 2019.

2.2 Participants

One hundred ninety-seven women were recruited from sport teams and gyms in the North of Portugal. The inclusion criteria were to be sportswomen, aged between 18 and 45 years, to be sexually active, and if parous, to be more than 1 year postpartum, performing sports at least 3 days a week for more than 1 year. The exclusion criteria were the inability to perform a correct PFM contraction or the inability to insert or maintain the vaginal probe due to pain or discomfort; to be a practitioner of multiple sports; surgical treatment of gynaecological and urological illnesses; urinary tract infections and pelvic organ prolapse.

2.3 Outcome measures

Each participant completed two questionnaires before the PFM assessment. The first was the socio-demographic questionnaire (demographic characteristics - age, obstetrics data, gynaecological surgery or pathology; anthropometric characteristics - body weight, height and training characteristics – years of training, hours of training per day and frequency of training per week). The second was the King's Health Questionnaire (KHQ). This was originally developed by Kelleher et al (1997) and designed to assess the impact of UI on the QoL of women, also evaluating urinary symptoms and subjective measures of severity (23). It was validated for the Portuguese population having obtained a good reliability. It is composed of 21 items investigating three domains and it evaluates the agreement of the subjects on a 4- and 5- option Likert scale: personal limitations and daily life, Emotions and Social relationship and Urinary symptoms. Additionally, it has an independent subscale designed as a Symptom Severity Scale. The KHQ scored from a minimum of 0 (best QoL) to a maximum of 100 (worst QoL), scored by every domain and by their global score. Scores of independent subscales were calculated in the same way (24).

The physiotherapist evaluated the sportswomen's ability to perform a correct PFM contraction. The manometry was performed using the Peritron manometer 9300 (LABORIE Medical Technologies Canada ULC.). The first measure to be evaluated by manometry was vaginal resting pressure (VRP) and the second was *MVC*. Measurements were obtained by the same researcher (TP), following standardized methodology. The vaginal probe was covered with a condom and before insertion the device was zeroed. The sportswomen were instructed to relax and contract the PFM. The lowest pressure value during rest was used as a measure of VRP. After zeroing the manometer, the participants were asked to perform an MVC, hold it for 3 seconds and the peak value was recorded. This was repeated 3 times and the mean value recorded (25). Between the VRP measurement and the MVC, the participants rested 5 seconds.

2.4 Data analysis

Data analysis was performed using SPSS, version 24 for Windows statistical analysis program (26). The variables were studied using absolute (n) and relative (%) frequencies (qualitative variables) and mean and standard deviation (quantitative variables). Pearson's Correlation Coefficient and Student's T-Test were used to study factors associated with QoL. Linear regression models were also used to study the factors that influence the overall QoL and its domains. Values with $P \leq 0.05$ were considered statistically significant.

3. Results

One hundred ninety-seven sportswoman were screened (n=197) and the table 1 presents the main characteristics of the sample. The VRP values ranged from 1.60 to 59.80 cmH_2O. The MVC values (mean of 3 evaluations) ranged from 18.90 to 136.50 cmH_2O (Table 1).

On average, the women in the sample practice physical activity for 201.7 minutes per week. The most practiced sports were strength training (39.1%) and gymnastics (15.2%). About half of them practiced low impact modalities (51.3%), with 46.2% practicing high impact activities and only 2.5% with medium impact (Table 2).

The KHQ Global score ranged from 0 to 95.83 (13.66±14.99). The mean KHQ domains show the existence of poorer QoL in Personal limitations and daily life (19.31±15.76) and Urinary symptoms (15.28±25.55) and better QoL in the Emotions and social relationships (6.39±16.06). Regarding the General Health Perceptions, the majority considered it to be very good (48.2%) or good (43.1%). Most reported that bladder problems do not affect their lives (69.0%). Of the 197 women participants, 9.6% stated that the bladder problem influenced their lives moderately (7.1%) or very little (2.5%). It is also added, in relation to the loss of urine during physical activity, that 11.7% of sportswomen lose a lot of urine and 8.6% lose moderately (Table 3).

Table 1 - Demographics and anthropometrics characteristics of the participants (n = 197).

Characteristics	**Mean±SD, range**
Age, years	29.85±8.60, 18-45
Weight, kg	61.55±9.67, 39-110
Height, m	1.65±0.08, 1.45-1.93
BMI[a], kg/m^2	22.52±3.38, 15.62-46.99
MVC[b], mmHg	62.06±25.65, 18.90-136.50

[a] BMI, Body mass index; [b] MVC, Maximum Voluntary Contractions; [c] VRP, Vaginal resting pressure.

As for the univariate analysis, the results of the association of the QoL (KHQ domains and global score) with the several variables included in the study are shown in Table 4. The results show the existence of significant positive correlations of age with total KHQ scores and all the domains, indicating that as age increases, the QoL assessed by KHQ decreases. The correlation is stronger with Personal limitations and daily life and with the Severity of symptoms. There were also significant positive correlations, but fewer correlations with BMI, indicating a trend of worse QoL with the increase in BMI. The correlations with weight were positive but of a low intensity, only the correlation of weight with Personal limitations and daily life was significant ($r = 0.161$, $p < 0.05$). These results show the existence of a slight tendency for the QoL to decrease with an increase in weight. On the contrary, correlations with height were negative, also of low intensity and not significant (except for the severity of the symptoms) ($r = -0.150$, $p < 0.05$), indicating a slight trend of better QoL in the taller women. Correlations with MVC and weekly sports practice were negative and significant, showing that higher values of MVC and longer physical activity lead to better QoL (which includes decreased urinary symptoms). A comparison of the mean QoL scores among women who practice low impact and high impact sports showed statistically significant differences in Personal limitations and daily life (p <0.001), in Emotions and social relationships (p = 0.021) and on the Severity of symptoms (p = 0.009). In these dimensions, women who practice high impact have a worse QoL than those who practice low impact sports.

Table 2 - Training characteristics (n = 197).

		n	%
Sports	Strength Training	77	39.1%
	Gymnastics	30	15.2%
	Crossfit	17	8.6%
	Volleyball	17	8.6%
	Pilates	16	8.1%
	Jumping	10	5.1%
	Indoor football	9	4.6%
	HIIT	5	2.5%
	Water aerobics	5	2.5%
	Horsemanship	2	1.0%
	Swimming	2	1.0%
	Others [a]	7	3.6%
Classification of sports [b]	IIA	16	8.1%
	IIIA	31	15.7%
	IB	18	9.1%
	IIB	20	10.2%
	IIIB	79	40.1%
	IC	1	0.5%
	IIC	8	4.1%
	IIIC	24	12.2%
Impact	Low	101	51.3%
	Medium	5	2.5%
	High	91	46.2%
Minutes per week	Minimum - maximum: 135 - 540; Mean±SD (201.7±107.8)		

[a] Cycling, Javelin Throw, Karaté, Pentathlon, Running (long distance), Running (sprint), Table tennis.

[b] IA – low static, low dynamic; IIA – moderate static, low dynamic; IIIA – high static, low dynamic; IB – low static, moderate dynamic; IIB – moderate static, moderate dynamic; IIIB – high static, moderate dynamic; IC – low static, high dynamic; IIC – moderate static, high dynamic; IIIC – high static, high dynamic (*Mitchell et al.*).

Table 3 - Prevalence of SUI and characteristics of leakage in sportswomen (n=197).

	n	%
KHQ_ Part_II _Q5 Stress incontinence: urinary leakage with physical activity (eg. coughing, sneezing, running)		
Does not affect	111	56,3%
A little	46	23,4%
Moderately	17	8,6%
Very	23	11,7%
KHQ_Part_III_Q2 Does your bladder problem affect your physical activities?		
Does not affect	119	60,4%
A little	33	16,8%
Moderately	21	10,7%
Very	24	12,2%

KHQ, King's Health Questionnaire; Q, question.

In order to study the influence that the various factors have on QoL, multiple regression models were performed considering, for each one, the variables of QoL (KHQ domains and Global score) with a dependent variable. As independent variables, we considered age, BMI (no age and weight due to BMI correlations), MVC, weekly sports practice time, and sports activity classification in relation to impact (the medium cases were not considered impact due to the reduced number of cases). The multiple regression models, in relation to the bivariate analysis of the previous section, have the advantage of obtaining the effect of each controlling variable for the other independent variables present in the models. (Table 5).

Results from the regression models (Table 5) show age as a risk factor for QoL in all domains (higher age, worse QoL), except for Urinary symptoms ($p = 0.853$): a one-year increase in the athletes' ages leads to an increase of 0.31 in the KHQ Global score, 0.64 in the Personal limitations and daily life score, 0.36 in the Emotions and social relationship score and 0.40 in the Severity of symptoms scale.

The increase in BMI was also significantly associated with a decrease in QoL ($p < 0.05$), except for the Severity of the symptoms ($p = 0.074$) and Personal limitations and daily life ($p = 0.071$). The increase of one unit in BMI is associated with an increase of 0.59 in the KHQ Global score, 0.56 in the Emotions and social relationship score and 1.29 in the Urinary symptoms.

Table 4 - Demographic/anthropometric characteristics and domains of the King's Health Questionnaire (n = 197).

	KHQ Global score	Personal limitations and daily life	Emotions and social relationship	Urinary symptoms	Severity of symptoms scale
Age, years	0.321**	0.413**	0.324**	0.107	0.445**
Weight, kg	0.140	0.161*	0.053	0.113	0.051
Height, m	-0.102	-0.022	-0.119	-0.091	-0.150*
BMI, kg/m^2	0.232**	0.196**	0.150*	0.192**	0.170*
MVC [a], cmH2O	-0.292**	-0.251**	-0.257**	-0.197**	-0.221**
Training time, min/week	-0.224**	-0.116	-0.164*	-0.219**	-0.249**
Impact [b]					
Low, mean±SD	12.31±11.21	15.55±12.13	4.00±10.65	17.38±26.50	9.18±10.57
High, mean±SD	15.66±18.38	23.81±18.21	9.39±20.45	13.80±24.92	14.09±14.84
Student's T test [c]	*p* = 0.125	*p* < 0.001	*p* = 0.021	*p* = 0.337	*p* = 0.009

[a] MVC, Maximum Voluntary contractions; Values of significance associated with the Pearson Correlation Coefficient: * p <0.05; ** p <0.01.

[b] the average impact due to the reduced number of cases was excluded.

[c] significance level of the *Student's T test* for the comparison of scores between "low" and "high".

MVC have a highly significant effect on overall QoL and its domains, showing that when adjusted for the other variables, the higher the MVC values, the better the QoL. Regression coefficients show that one-unit increase of MVC leads to a decrease of 0.14 in the KHQ Global score and in the Personal limitations and daily life score, 0.09 in the Emotions and social relationship score, 0.08 in the Severity of symptoms scale and 0.18 in the Urinary symptoms score, an increased value of MVC decreased urinary symptoms.

The weekly time of physical activity is associated with a better QoL in symptomatology, but it has no significant effect on total QoL or its domains (p > 0.05).

The practice of high-impact activities decreases QoL (compared to low-impact activities) in Personal limitations and daily life and in the Severity of symptoms, but has no significant effect on the overall QoL (p = 0.972) nor on the domains of Emotions and social relationship (p = 0.197) and Urinary symptoms (p = 0.748).

Table 5 - Factors influencing Quality of Life (Kings Health Questionnaire) - linear regression models (n = 197).

Variables	*Models*				
	KHQ[c] Global score	Personal limitations and daily life	Emotions and social relationship	Urinary symptoms	Severity of symptoms scale
Age, years	B = 0.31, β = 0.22, *p* = 0.007	B = 0.64, β = 0.37, *p* < 0.001	B = 0.36, β = 0.28, *p* = 0.001	B = -0.05, β = -0.02, *p* = 0.853	B = 0.40, β = 0.30, *p* < 0.001
BMI, kg/m^2	B = 0.59, β = 0.16, *p* = 0.019	B = 0.52, β = 0.12, *p* = 0.071	B = 0.56, β = 0.17, *p* = 0.014	B = 1.29, β = 0.17, *p* = 0.018	B = 0.39, β = 0.12, *p* = 0.074
MVC[a], cmH_2O	B = -0.14, β = -0.29, *p* < 0.001	B = -0.14, β = -0.24, *p* < 0.001	B = -0.09, β = -0.20, *p* = 0.003	B = -0.18, β = -0.18, *p* = 0.010	B = -0.08, β = -0.18, *p* = 0.005
Training time (min/week)	B = -0.01, β = -0.07, *p* = 0.379	B = 0.01, β = 0.04, *p* = 0.620	B = 0.00, β = -0.01, *p* = 0.943	B = -0.04, β = -0.17, *p* = 0.045	B = -0.01, β = -0.14, *p* = 0.071
Impact [b]	B = 0.07, β = 0.00, *p* = 0.972	B = 4.60, β = 0.15, *p* = 0.036	B = 2.24, β = 0.10, *p* = 0.197	B = -1.31, β = -0.03, *p* = 0.748	B = 4.52, β = 0.20, *p* = 0.007
R^2	19.8%	26.4%	19.2%	10.7%	27.6%

β - Standardized regression coefficient; B - Non-standard regression coefficient; *p* - significance value of regression coefficients.
[a] MVC, Maximum voluntary contractions.
[b] high impact activities relative to low impact activities.
[c] KHQ kings health questionnaire.

4. Discussion

The mean of the VRP was 24.34 (11.00) cmH_2o. In a similar study by Tennfjord et al. (27), the participants were tested twice by examiners on day and retested after 1 week by one examiner. The mean of VRP was 24.36 (9.50) cmH_2o and 21.93 (6.96) cmH_2o, in Test 1 and Test 2, respectively, using the similar manometer. The authors concluded that the test results were reproducible, because the study showed very good Intraclass correlation coefficient values (>0.90). This is in line with the findings of previous studies that used different types of manometers (25, 28). It is not easy to quantify as there is a lack of data on normal values for the resting condition of the PFM (27, 29).

The main results were that the MVC values have a highly significant effect on both the overall QoL and all the domains (Personal limitations and daily life, Emotions and Social relationship and Urinary symptoms), showing that when adjusted for the other variables, the higher the MVC values, the better the QoL. It is noteworthy that increased MVC decreased urinary symptoms. It is very important that athletes learn to perform it to strengthen the PFM, considering they are the only muscle groups in the body capable of giving structural support for the pelvic organs and the pelvic openings (urethra, vagina and anus) (4), thus preventing SUI (4, 17, 30). Several studies have concluded that PFMT is the first line of treatment for urinary symptoms or SUI (7, 19-22). Thomaz et al (11) also reported this is important for physiotherapists and patients, since it may help prevent urinary symptoms.

Similar to what was reported in the study of Simeone et al (31), age, type of sport, number of hours of training, number of years an athlete is involved in sport, and the competitive level are all predictive factors for urinary disorders and UI.

Another important result was that the practice of high-impact activities decreases the QoL (compared to low-impact activities). Several studies point to high impact sports as one of the most demanding factors of SUI (2, 3, 6, 9, 10). Bo (2004) corroborated that any physical activity that increases abdominal pressure will lead to simultaneous or pre-contraction of the PFM, meaning they will be trained, which should prevent and treat SUI. However, several athletes do not demonstrate simultaneous or pre-contraction of PFM effectively during increased abdominal pressure and they leak urine (4). Moser et al, also support these two hypotheses, that high-impact sports could strengthen the PFM, or it may damage the structures of the pelvic floor by overloading and weakening it (6). This can happen when the strenuous physical activity that involves intra-abdominal pressure overloads and chronically damages the perineum (6) or causes muscle fatigue. During physical activity type II, fibers are recruited, which have a low capacity for maintaining the muscle tone of the PFM (11, 32). Kruger et al, explained that an increase in the cross-sectional area of PFM in women practicing high-impact activities support the strengthening theory (33). In fact, the prevalence rates of SUI in athletes practising high-impact sports remain high. Borin et al, reported in their study that 20% of volleyball and handball athletes and 10% of basketball athletes suffered from SUI (34). Da Roza et al, concluded in two studies that 72,7% and 49,4%, respectively had SUI (2, 35). Jácome et al (8) reported 61,4% and Póswiata et al (36), found 45, 5% of SUI in athletes.

An interesting result was that the weekly time of physical activity is associated with a better QoL in symptomatology. Pucci et al, concluded in its systematic review, that there is a positive association between physical activity and QoL, which varies according to the domains of QoL assessed (37). Vuillemin et al, corroborated, that the recommended levels of physical activity were associated with higher health-related QoL scores (38). The QoL is a conscious cognitive judgment of satisfaction with one's life, within a sociocultural context with regards to their aims (38). However, many athletes/sportswomen considered SUI to have implications in the QoL and on sports performance, using strategies to hide the leakage and hide from health professionals, believing that UI is common (31, 36, 39).

Age and BMI can be a predictor of SUI, according to this study. In a systematic review with seven studies, Almousa et al concluded that age and BMI were identified to be positively associated with UI, among other factors (40). The same author argued that as people age, and with the loss of estrogen occurring with menopause, the muscles in the bladder and urethra tissues weaken, leading to urine leakage (40). Regarding BMI, Almousa et al explained that an increase in BMI leads to increase in weight. Consequently, the chronic increase in intra-abdominal pressure leads to an increase in intravesical pressure, which overcomes the urethral closing pressure and leads to UI (40). It has been reported that each five-unit increase in BMI raises the risk of UI by 20–70% (41).

A limiting factor was that the sportswomen were not all nulliparous and the sample could be more homogeneous. Another bias of the study was not being able to apply the *pad test*, in order to quantify the urine loss of each participant. Findings from the present study must be interpreted in light of these limitations. Future research is warranted, namely randomised controlled trials to provide data to guide the clinical practice of professionals based on evidence.

5. Conclusion

This study revealed a positive association between MVC and the weekly time of physical activity in the QoL. Increased MVC values lead to decreased urinary symptoms. High age and BMI, together with high impact sports seem to be risk factors for decreased QoL in women with urinary symptoms. It also highlights the important role of all professionals involved in sports, such as coaches, physiotherapists, fitness instructors and sports doctors in the prevention of SUI by showing the necessity of including PFM exercises in the training routine. Sportswomen should be encouraged to practice organized exercises by following a training protocol and to follow the American College of Sports Medicine recommendations in order to reap the health benefits of exercise without being afraid of developing SUI.

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CHAPTER 4 – PELVIC FLOOR MUSCLE TRAINING IN FEMALE ATHLETES: A RANDOMIZED CONTROLLED PILOT STUDY

Pires, T., Pires, P., Moreira, H., Gabriel, R., João, P., Viana, S., Viana, R. (2020). Pelvic floor muscle training in female athletes: a randomized controlled pilot study. *International Journal of Sports Medicine*, 41: 264-70. DOI: 10.1055/a-1073-7977.

Abstract

The aim of this study was to investigate the effects of pelvic floor muscles training in elite female volleyball athletes and whether it is an effective therapy for stress urinary incontinence. Fourteen athletes, both continent and incontinent, between 18 and 30 years of age, were randomly assigned to an experimental group or a control group. The experimental group received a protocol for pelvic floor muscle training for 4 months. This consisted of three phases: awareness/stabilization, strength training and power. The control group was not subject to any intervention during the same period. Measures were collected at the initial and final phase for both groups. Maximum voluntary contractions were evaluated with a perineometer, involuntary urine loss with a Pad test and quality of life with the King's Health Questionnaire. Baseline sociodemographic and anthropometric characteristics were not significantly different. Comparing the two groups, the experimental group improved maximum voluntary pelvic contractions ($p < 0.001$) and reduced urine loss ($p=0.025$), indicating the existence of significant differences between groups in the variation from the initial and final phases. The percentage of urine loss decreased in the experimental group, from 71.4% to 42.9%, suggesting that the protocol intervention for 16 weeks may help athletes with stress urinary incontinence. Further research is warranted to assess the sustainability of the findings.

Clinical Trial Registration: ClinicalTrials.gov NCT03938779, URL: www.clinicaltrials.gov

Keywords: Elite Female athletes, pelvic floor muscles training, maximum voluntary contractions, stress urinary incontinence.

Introduction

Female athletes are at risk of injuries common to sports that involve the musculoskeletal system and high impact exercises, predisposing them to stress urinary incontinence (SUI) [1]. The International Urogynecological Association (IUGA)/International Continence Society (ICS) defines SUI as the complaint of involuntary loss of urine on effort or physical exertion or sneezing or coughing [2]. Recent studies have reported that young women practicing high impact sports, such as volleyball, are considered to be at a greater risk for developing SUI [3-6]. SUI in athletes tends to be related to how frequently they are subjected to increased intra-abdominal pressure, which is caused by a contraction of the abdominal muscles in high-impact activities without proper awareness and strengthening of the perineal muscles [1-2, 4]. Maximum Voluntary Contractions (MVC), as well as pelvic floor muscles (PFM), are important for maintaining continence throughout lifetime. Their dysfunction may affect the quality of life (QoL), causing discomfort, constraint, anxiety and a decreased participation in social activities [3, 5].

The mechanism of continence demands a complex coordination of the PFM, the urethra, the bladder and the supporting ligaments. This mechanism includes striated (voluntary control) and smooth (involuntary) muscles. Striated muscles adapt to the requirements of training programs based on the principles of exercise physiology: specificity, overload and reversibility. The increase in strength in the first 6 to 8 weeks is predominantly neural (frequency of activation and recruitment of motor units). Hypertrophy may also begin between 6 and 8 weeks and may last for years. Although it is generalized to all fibers, the potential for hypertrophy is greater in fast rather than slow fibers. Pelvic floor muscle training (PFMT) alters muscle morphology by increasing the sectional area. It also modifies neuromuscular function by increasing the ability to recruit additional motor units and the frequency of arousal. In addition, it improves muscle tone and the viscoelastic properties of the connective tissue. PFMT is a progressive training of specificity, intensity, rest time, frequency, volume and duration [3].

A lot of studies have concluded that PFMT is an effective therapy for SUI [1, 7-9]. To date, a few randomized controlled trials have studied the effectiveness of the PFMT intervention in improving urinary symptoms in elite female athletes. The hypothesis of this study was to investigate whether PFMT can improve the amount of urine loss and MVC in PFM.

Materials & Methods

Study design

This study was a randomized controlled trial with concealed allocation and intention-to-treat analysis. Athletes were randomly assigned to receive PFMT (Experimental Group-EG) and no intervention (Control Group-CG), using a computer-generated Schedule in two random groups (http:// www.randomization.com). Each athlete randomly removed a number (ranging from 0-14) from an envelope, which was the number placed in the program. Participants knew about the existence of two groups but not the differences between them (EG with intervention and CG with no intervention). The trial was registered at ClinicalTrials.gov (NCT03938779) and was reported according to CONSORT guidelines [10]. Ethical approval was obtained from the Ethics Committee of the University of Trás-os-Montes e Alto Douro (UTAD), Vila Real, Portugal (25/2017) and was approved by the Ethics Committee of the institutions involved, meeting the ethical standards of the journal [11]. All participants provided informed consent and behaved according to the Declaration of Helsinki.

Patients of both groups underwent an initial (January 2019) and final evaluation (4 months later, May 2019). This evaluation consisted of measuring the MVC through the perineometer and the Pad test. Additionally, the EG received a PFMT intervention.

Participants

Thirteen participants were recruited for this study. The sample recruited were elite female volleyball athletes. These were included if they were 18 years or older, elite female volleyball athletes, nulliparous, and able to provide informed consent. Exclusion criteria consisted of the inability to perform a correct PFM contraction or the inability to insert or maintain the vaginal probe due to pain or discomfort, irregularity of sport performance, surgical treatment of gynecological and urological illnesses, urinary tract infections, and pelvic organ prolapses.

Intervention

Pelvic Floor Muscles Training

The EG were also instructed to perform daily PFMT at home and extra training. This consisted of exercise training and education sessions. Exercise training was held for 16 weeks (due to the time interval between the two internship moments of the national team), with a physiotherapist's daily alert for the training time. The efficacy of training depends on exposure of the isolated muscle to a sufficient load intensity, duration, frequency and adherence to maintenance protocols of training [12]. The aim is to strengthen the phasic and tonic fibers by performing intense short-term contractions (Type II fibers) combined with longer-lasting submaximal contractions (Type I fibers) [13].

The PFMT consisted of three phases, which are listed below:

I Awareness / stabilization (at home): 2 weeks, aimed to acquire the awareness and perception of the PFM, its location and ability to contract them properly and create postural and respiratory dynamics. The progression of the exercises/positions occurred in the sense of increased gravity, i.e., the exercises began in the lying position and gradually evolved into a standing position; it consists of the same time for contraction and relaxation (10 sec; 10x).

II Strength training (at home): 2 weeks, aimed to promote the strengthening by progressively increasing strength, by recruiting more motor units and the hypertrophy of PFM. The contraction time was greater than the relaxation time, progressively increasing the level of difficulty over time [Exercises: 1st and 2nd, contract 6sec and relax 3sec (5x); 3rd contract 5sec and relax 2sec (5x); 4th contract 10 sec and relax 2sec (5x); 5th contract 5 sec and relax 2sec (5x); 6th contract 8 sec and relax 4 sec (5x); 7th contract 6 sec and relax 3 sec (5x); 8th contract 10 sec and relax 2sec (5x)]

III Power (in training): 12 weeks (divided into two parts, the first lasting 4 weeks and the second lasting 8 weeks). It consists of improving the PFM's reaction capacity and consequently increasing its mechanical efficiency in situations of increased intra-abdominal pressure, with training being a mixture of speed and strength. In Part I, the athletes were required to do pelvic floor power based on general exercises, while in Part II they performed specific exercises according to the sport played, in order to incorporate the exercises into their daily practice [14-16]. This phase was adapted to the athlete's training. Each athlete must perform a knack technique (rapid and strong contraction, in well-timed, 1/2 sec, immediately before and during any increase in downward pressure on the pelvic floor, according to each exercise requested by the coach. The number of series depends on what is requested by the coach.

An initial meeting was held, where all athletes were instructed on the training objective and exercises, number and duration of contractions, contraction and relaxation times, fast/sustained contraction, intensity and frequency. An App, 'PhysioPelvic', illustrating the exercise program was provided to the participants to be used for home exercises. All athletes of EG adhered and completed the PFMT.

Maximum Voluntary Contractions

The physiotherapist evaluated the athlete's ability to perform a correct PFM contraction. The PFM contractility evaluation was performed by the physiotherapist at baseline. It was conducted first by digital palpation, where the index and middle fingers were introduced 2-3 centimeters into the vaginal introitus, with the athlete being asked to squeeze the fingers of the physiotherapist to overcome resistance and to do the same with the perineometer probe [17].

The vaginal resting pressure and then the MVC were evaluated using the manometry (Peritron perineometer 9300, LABORIE Medical Technologies Canada ULC.), which has been found to be a reliable method of measuring MVC. The participants were lying on a clinic table in the supine position, with a lower limb abduction and knee flexion. The measurements were obtained by the same researcher, following a standardized methodology. First, the vaginal probe was covered with a condom and before insertion the device was zeroed. The athletes were then instructed to relax and to contract the PFM. The lowest pressure value during rest was used as a measure of vaginal resting pressure. After zeroing the perineometer, the participants were asked to perform an MVC, hold it for 3 seconds and the peak value was recorded. This procedure was repeated 3 times and the mean value was recorded [18].

Pad Test

The pad test quantifies the urine loss based on measuring the weight gain of absorbent pads over a period of testing under standard conditions. It is a non-invasive, inexpensive and an objective method [19]. Several standards have been developed, where the tests can usually be divided into the following four groups: <1 hour; 1 hour; 24 hours and 48 hours. In this study, the pad test was modified according to the duration and training load of the athletes. This pad test lasted 2 hours, was included in training and could not be interrupted during this time. The athletes were asked to empty their bladders before training, although no bladder volume was measured. The standard 1-hour Pad Test consists of drinking 500 ml of water before starting the test, followed by 30 minutes of going up and down some flights of stairs. Then they sit and stand 10 times, run a minute in the same spot, pick up an object from the ground 5 times, vigorously cough 10 times and, finally, wash their hands for 1 minute [19].

This study used a modified 2-hours pad test, consisting of drinking 1000 ml of water before starting the test, followed by 1 hour of going up and down some flights of stairs, sitting and standing 20 times, running 2 minutes in the same spot, picking up an object from the ground 10 times, vigorously coughing 20 times and, finally, washing their hands for 2 minutes

King's Health Questionnaire

The King's Health Questionnaire (KHQ) was originally developed by Kelleher et al (1997) and created in order to assess the impact of UI on QoL of women, as well as to evaluate urinary symptoms and their subjective measures of severity [20]. It was validated for the Portuguese population having obtained a good reliability. It is composed of 21 items covering three domains and it evaluates the agreement of the subjects on a 4- and 5- option Likert scale, which are the following: Personal limitations and daily life, Emotions and Social relationship and Urinary symptoms. Additionally, it has an independent subscale designed as a Symptom Severity Scale. The KHQ scored from a minimum of 0 (best QoL) to a maximum of 100 (worst QoL), scored by every domain and by their global score. Scores for the independent subscale were calculated in the same way [21].

Participants' characteristics

Sociodemographic and anthropometric data were collected using a structured questionnaire.

Statistical analysis

Data analysis was performed using IBM SPSS, version 24 for Windows statistical. Student's t-tests were used for independent samples (a comparison between CG and EG groups) and paired samples (a comparison between the initial and final phases). ANOVA was used for repeated measures with the following two factors: time (initial and final phase) and group (CG and EG). The interaction term time * group was used to assess whether there were significant differences between the two groups regarding the variation of the perineometry and the pad test between the initial and final phases. The assumptions for using these tests were tested and validated by the Shapiro-Wilk Test (data normality), the Levene Test (homogeneity of variances) and the M Box Test (covariance matrix homogeneity in ANOVA). A significance level of 5% was considered.

Results

Participants

Seventeen elite female volleyball athletes were screened (Figure 1). However, three were excluded for not meeting the inclusion criteria (n=1) or declining to participate (n=2).

Therefore, 14 patients were allocated to the EG (n=7) or CG (n=7). Thirteen participants completed the intervention and post-test assessments and thus were included in the analysis. Athletes had a mean age of 22.3 years old and the mean body mass index was 21.5 kg/m^2.

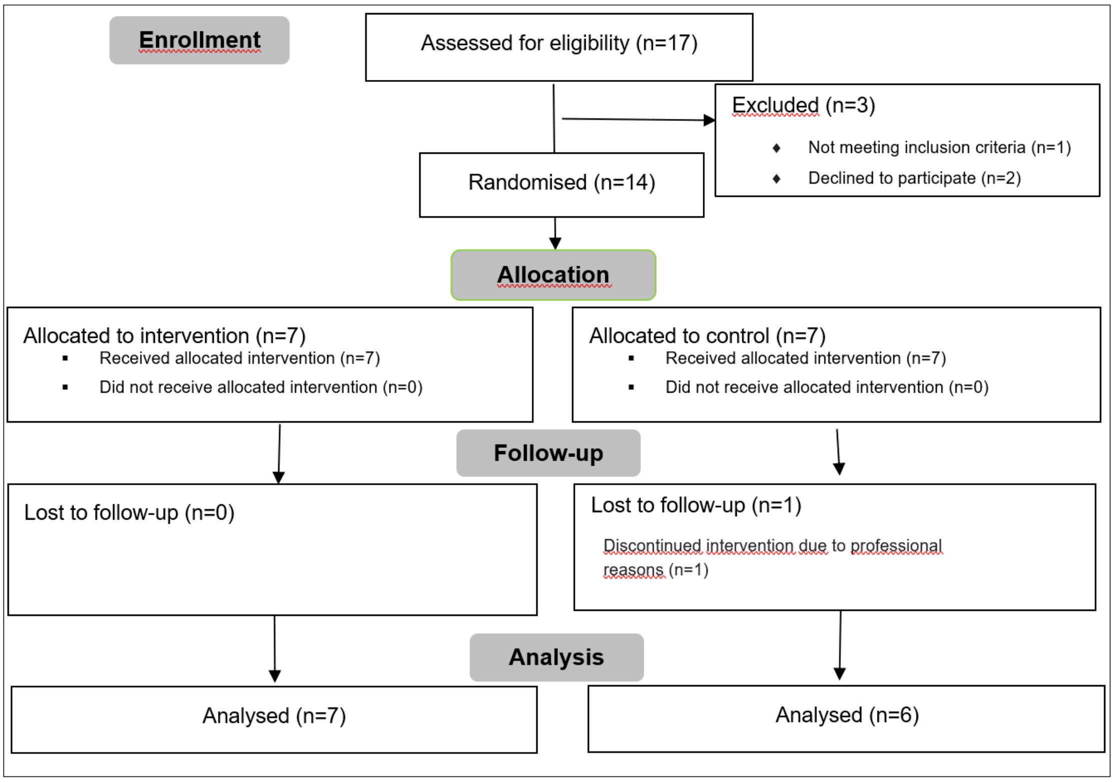

Figure 1 - Flow diagram.

No significant differences were found among the group in their baseline characteristics (Table 1). All participants are considered elite female athletes because they are part of the Portuguese Women's Volleyball Federation. They are professional athletes who train daily (5x90min) for a total of 450 min/week.

The mean *vaginal resting pressure* decreased in both groups, in EG (p = 0.100) and CG (p = 0.428). The interaction time * group was not significant (*p = 0.533*), indicating the existence of not significant differences between groups in the variation from the initial to final phase (Table 2).

Table 1 - Physical characteristics of the participants (n=13).

Variables	CG (n = 6)	EG (n = 7)	Student's t-test *(p)*
Age (years)	21.83 (5.19) 18 - 31	22.71 (4.99) 18 - 30	0.762
Weight (kg)	74.17 (6.77) 64 - 82	67.86 (9.28) 52 - 78	0.196
Height (m)	1.85 (0.07) 1.74 - 1.93	1.78 (0.11) 1.57 - 1.92	0.260
BMI (kg/m^2)	21.75 (0.97) 20.67 - 22.96	21.37 (2.14) 17.53 - 23.84	0.697

BMI, body mass index; CG, control group; EG, experimental group; Data are presented as mean (standard deviation) and range.

The mean *MVC* increased significantly in EG (p <0.001). In CG there were no significant differences (p=0.700). The interaction time * group was significant (p<0.001), indicating the existence of significant differences between groups in the variation from the initial to final phase (Table 2).

Table 2 Changes in vaginal resting pressure and MVC (mmHg) between initial and final evaluation in the experimental group (EG; n=7) and in the control group (CG; n=6).

	Mean scores (SD)		Variation	Student's
	Initial	Final	Initial-Final	t-tests [a]
Vaginal resting pressure				
CG (n=6)	16.18 (15.71)	13.67 (8.80)	-2.51 (7.16)	p = 0.428
EG (n=7)	17.33 (7.74)	12.31 (3.70)	-5.02 (6.82)	p = 0.100
		*Interaction time * group [b]: p = 0.533*		
MVC				
CG (n=6)	55.68 (29.12)	55.13 (30.97)	-0.55 (3.28)	*p* = 0.700
EG (n=7)	60.80 (19.72)	78.75 (18.36)	17.95 (4.29)	***p* < 0.001**
		*Interaction time * group [b]:* ***p < 0.001***		

CG, control group; EG, experimental group; MVC, maximum voluntary contractions; [a] Comparison between initial and final, within each group - Student's t-test of repeated measures; [b] Significance value of the interaction term time * repeated measures ANOVA group with time and group factors.

For the *Pad test*, there was a significant reduction in the mean EG (p=0.025) from 2.71±2.14 in the initial phase to 1.29±1.70 in the final phase. In CG there were no significant differences between the initial (1.83±2.40) and final phases (2.00±1.67) *(*p=0.741). The interaction time*group was significant (p=0.039), indicating the existence of significant differences between groups in the variation from the initial to final phases (Table 3). The percentage of urine loss decreased in EG, to 42.9% (n=3) and increased in CG, to 83.3% (n=5) (Table 4).

Table 3 - Pad test (g) comparison between initial and final evaluation in the CG and EG.

	Mean scores (SD)		Variation	Student's
	Initial	Final	Initial-Final	t-tests [a]
Pad test				
CG (n=6)	1.83 (2.40)	2.00 (1.67)	+0.17 (1.17)	*p* = 0.741
EG (n=7)	2.71 (2.14)	1.29 (1.70)	-1.43 (1.27)	***p* = 0.025**
		*Interaction time*group [b]: **p = 0.039***		

CG, control group; EG, experimental group; [a] Comparison between initial and final, within each group - Student's t-test of repeated measures; [b] Significance value of the interaction term time * repeated measures ANOVA group with time and group factors.

Table 4 - Percentage of urine leakage in CG and EG at initial and final evaluation.

	Initial n (%)		Final n (%)	
Pad test (g)	No loss of urine	Loss of urine	No loss of urine	Loss of urine
CG (n=6)	3 (50.0%)	3 (50.0%)	1 (16.7%)	5 (83.3%)
EG (n=7)	2 (28.6%)	5 (71.4%)	4 (57.1%)	3 (42.9%)
Total (n = 13)	5 (38.5%)	8 (61.5%)	5 (38.5%)	8 (61.5%)

The results of the KHQ are presented in Table 5. The KHQ Global score ranged from 0 to 13.89 (6.35±5.19) in EG and 0 to 12.50 (8.80±4.62) in CG. The mean KHQ domain Personal limitations and daily life was higher in CG than in EG and Emotions and social relationships were 2.08±3.49 in CG and 1.19±2.03 in EG. Regarding the Severity of symptoms scale, the values were 6.06±3.32 in CG and 6.93±5.16 in EG. There were no significant differences between the EG and CG.

Table 5 shows the results of the QoL evaluated by the KHQ before the intervention. The mean global score was low in both groups (8.80 ± 4.62 in CG and 6.35 ± 5.19 in EG), indicating a high QoL. Concerning the KHQ domains, the QoL in Personal limitations and daily life (24.31 ± 12.20 in CG and 17.86 ± 14.17 in EG) was poorer than in Emotions and social relationships (2.08 ± 3.49 in CG and 1.19 ± 2.03 in EG), and in the Urinary symptoms domain (0.0 ± 0.0 in both groups). There were no significant differences between the two groups ($p > 0.05$) in any of the domains of KHQ.

Table 5 - Domains of the King's Health Questionnaire, at initial evaluation (n = 13).

Variables	CG (n = 6)	EG (n = 7)	Student's t-test *(p)*
Global score	8.80 (4.62) 0.00 - 12.50	6.35 (5.19) 0.00 - 13.89	0.392
Personal limitations and daily life	24.31 (12.20) 0.00 - 33.33	17.86 (14.17) 0.00 - 37.50	0.402
Emotions and social relationships	2.08 (3.49) 0.00 - 8.33	1.19 (2.03) 0.00 - 4.17	0.577
Urinary symptoms	0.00 (0.00) 0.00 - 0.00	0.00 (0.00) 0.00 - 0.00	-
Severity of symptoms scale	6.06 (3.32) 0.00 - 9.09	6.93 (5.16) 0.00 - 12.12	0.732
General health perceptions	8.33 (12.91) 0.00 - 25.00	7.14 (12.20) 0.00 - 25.00	0.867
Incontinence impact	16.67 (27.89) 0.00 - 66.67	19.05 (17.82) 0.00 - 33.33	0.855

CG, control group; EG, experimental group; Data are presented as mean (standard deviation) and range.

In Table 6, the prevalence of SUI and the characteristics of leakage in the two groups is a supplement to the Pad test as it helps us clarify athletes who have SUI by presenting symptoms. In EG, 57.1% of athletes responded 'moderately' regarding loss of urine due to stress and ‘a little’ regarding how their bladder problem affects their physical activities. In CG, 33.3% responded ‘moderately’ regarding loss of urine due to stress and 83.3% of athletes responded ‘a little’ regarding how their bladder problem affect their physical activities.

Table 6 - Prevalence of SUI and characteristics of leakage in two groups, at initial evaluation (n=13).

	CG (n = 6)		EG (n = 7)		P value
	n	%	n	%	
KHQ_Part II_Q5					
Stress incontinence: urinary leakage with physical activity (eg. coughing, sneezing, running)					
Does not affect	2	33.3%	2	28.6%	0.790[a]
A little	2	33.3%	1	14.3%	
Moderately	2	33.3%	4	57.1%	
Very	0	0.0%	0	0.0%	
KHQ_Part III_Q2					
Does your bladder problem affect your physical activities?					
Anything	1	16.7%	2	28.6%	1.000[a]
A little	5	83.3%	4	57.1%	
Moderately	0	0.0%	1	14.3%	
Very	0	0.0%	0	0.0%	

CG, control group; EG, experimental group; KHQ, King's Health Questionnaire; Q, question; [a] Fisher's exact test.

Discussion

This was the first randomized controlled trial that evaluated MVC and Pad test on elite female volleyball athletes. The findings suggest that this intervention is feasible and that it enhances athletes' MVC and decreases the loss of urine. The differences between groups may be explained by the efficacy and duration of the PFMT program (16 weeks). This protocol has been applied with varied degrees of success in interventions conducted with other populations, health behaviours and different durations [14-15]. In their study, Thuane et al [14], concluded that this PFMT increased PFM strength (from 73.4±24.9 to 89.8±19.1 cmH_2O) and reduced the frequency and amount of UI episodes (from 1.6±1.5 to 0.1±0.4 g) in sport students that completed an 8-week PFMT program. According to Sousa et al [15], the PFMT protocol has shown to be effective in reducing loss of urine (from 1.34±0.4 to 0.93±0.3 g) and increasing PFM strength (from 34.61±0.5 to 54.59±11.2 Pa). There are other PFMT protocols, but they all seem to contribute to an increase in PFM strength and to be an effective therapy for SUI [7, 9, 14, 22].

A previous study stated that the prevalence of SUI among young nulliparous elite athletes varies between 0% (golf) and 80% (trampolinists). The highest prevalence is found in sports involving high-impact activities such as gymnastics, track and field, and some ball games [3]. The prevalence of this study was no exception. The initial prevalence of SUI in the EG was 71.4% (n=5) and the final figure was 42.9% (n=3) (Table 3). This high prevalence may be justified by the association between urine leakage and PFM strength. Because volleyball is a high-impact sport, these exercises may cause PFM disorders due to a frequent increase in the intra-abdominal pressure or by the reaction with ground forces [15]. In the CG, the initial prevalence of SUI was 50% (n=3) and in the final figure was 83.3% (n=5). The reason for this may be because the CG did not receive any teaching, prevention or treatment to strengthen their PFM. Once again, this reinforces the idea that SUI is mainly related to bladder neck hypermobility of weak or damaged PFM, pelvic ligaments and laxity of the urethral fascia [23], which means the structural changes of the neuromuscular and connective tissues supporting the bladder neck and urethra [24]. If athletes continue without strengthening the PFM, the loss of urine may be maintained or even increased.

The mean *vaginal resting pressure* decreased in both groups. Although only the EG performed the PFMT, the truth is that in the initial phase both groups received information about the constitution / function of the PFM, as well as awareness of them, in order to better accomplish the MVC. This means that the athlete was assisted to ensure they contracted the correct muscle during the MVC, thus avoiding the concomitant contraction of other muscles such as the rectus abdominis, the thigh adductor and the gluteus maximus (accessories), which considerably decreases the contractile activity of the MPP [25].

The QoL is a conscious cognitive judgment of satisfaction with one’s life, within a sociocultural context with regards to their aims. However, many athletes considered SUI to have implications in their QoL and on sports performance. They use strategies to hide the leakage and hide from health professionals, believing that UI is common [26]. There was an exception in this study, as the athletes felt that they did not lose urine when completing their KHQ (Table 5), perhaps because this self-declared questionnaire does not always correspond to reality, since it is subjective. With the evaluation of the pad test, it was found that there was some lost urine after all, which was an objective and more reliable evaluation tool.

SUI can be a barrier to women’s participation in sport and fitness activities; therefore, it may be a threat to women’s health, self-esteem and well-being [22]. The costs associated with the addition of the PFMT were relatively small as well as the time needed by the physiotherapist to provide support (approximately 20 minute/training). Thus, this intervention can be implemented in various women’s teams, without the need for significant additional costs or human resources, so that SUI may no longer be an obstacle for these athletes. Further research is needed to study the cost-effectiveness of this PFMT protocol. Therefore, the hypothesis of changing lifestyle after the intervention translates into better measures related to improving quality of life [14]. Future research should apply a PFMT protocol.

Limitations of study

The conclusions of this study should be interpreted in light of its limitations. This was a small-scale trial; therefore, the generalization of the results to clinical practice is limited. It was not possible to carry out the assessor blinding. Future research is needed to explore whether a larger sample of high-performance athletes would present similar results after the intervention.

Conclusions

The PFMT may improve urinary symptoms by decreasing urine loss and increasing the PFM strength. The success of the PFMT depends on the ability to identify the PFM and the integration of the perineal region in the body scheme, awareness of the correct contraction and adherence to the exercise protocol. Further research with larger samples and follow-up assessments is warranted to support these preliminary findings and assess the short-and long-term impact of this intervention in SUI.

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Declaration of Conflicting Interests

The authors declare that there is no conflict of interest.

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CHAPTER 5 – LEG STIFFNESS AND MUSCLE POWER VS PERINEOMETRY IN SPORTSWOMEN WITH SYMPTOMS OF STRESS URINARY INCONTINENCE

Pires, T., Pires, P., Moreira, H., Gabriel, R., Reis, A., Viana, S., Viana, R. (submitted). Leg stiffness and muscle power vs perineometry in sportswomen with symptoms of stress urinary incontinence. *Clinical Biomechanics*.

Abstract

Background: To evaluate maximum voluntary contractions of the pelvic floor muscle in sportswomen and verify the association with leg stiffness and muscle power, both maximal and submaximal.

Methods: The sample of this cross-sectional study consisted of 41 sportswomen between 18 and 42 years of age. Pelvic floor muscle strength was measured by the perineometer. The sportswomen were instructed to perform 3 maximum voluntary contractions of the perineum, held for 3 seconds. The maximal and submaximal leg stiffness and muscle power were measured with a force platform. The sportswomen were instructed to perform the following protocol: five-minute individual warm-up, subjects familiarized themselves with the hopping test routine for each condition: bilateral.

Findings: Maximal and submaximal leg stiffness values increase with increasing age, weight, height, and BMI, showing positive (R between 0.233 0.478) and significant ($p < 0.05$) or close correlations. Correlations with maximum voluntary contractions are not significant ($p > 0.05$). There are strong positive correlations between maximal and submaximal leg stiffness ($R = 0.759$) and between maximal and submaximal muscle power ($R = 0.496$). Maximum voluntary contractions values decrease with increasing K_N: the correlation is significant with maximal leg stiffness ($R = -0.488$), but weak and not significant with submaximal leg stiffness ($R = -0.191$).

Interpretation: Maximum voluntary contractions values decrease with increasing leg stiffness and increase with increasing muscle power values. This value may be associated with a higher muscle power during the maximum exercise. If training is prepared to increase muscle power, maybe increase to maximum voluntary contractions.

Keywords

Leg stiffness, Maximum Voluntary Contractions, Pelvic floor muscles, Power, Sportswomen, Stress urinary incontinence.

1. Introduction

The pelvic floor muscles (PFM) consists of the pelvic and urogenital diaphragm (1) and contribute to the continence mechanism with contractions that are rapid, strong and reflexive (2-4). This function is “the ability to contract and relax the PFM voluntarily and involuntarily” (5). Pelvic floor muscle training can be a protective factor, therefore it is very important that every woman learns how to perform maximum voluntary contractions (MVC) to prevent stress urinary incontinence (SUI) and other pelvic floor dysfunctions (1, 6, 7). SUI is the most frequent form of urinary incontinence in women (8). Several studies have documented that young women, especially those practicing high impact sports, are considered to be at a high risk for developing SUI (9-12). There is a strong relationship between physical activity and SUI (12-15). Intense physical activity promotes an increase in intra-abdominal pressure and the repetitive increases may lead to weakness and stretching of the PFM and consequently to SUI (16-18). This increase in abdominal pressure results in morphologic and functional modifications, such as deformation of ligaments and connective tissue (7, 19).

When we talk about physical activity, namely high impact activities, such as ‘jumping’, it is necessary to understand if ‘Leg stiffness’ and ‘Muscle Power’, including anatomical structures, can affect the MVC values.

The definition of ‘*Stiffness’* is based on Hooke’s law, which states that the force required to deform an object is linked to a proportionality constant (spring) and the distance that object is deformed (20-22). This definition also considers that the human body, or body segments, is often modeled as a spring (21). Stiffness in the human body (or body segments) refers to its ability to resist deformation or change when ground reaction force or moments are applied (23), involving the complex interaction of anatomical structures (bone, cartilage, muscles, ligaments and tendons) (21, 24).

Most models of leg and joint stiffness have originated from the measure of vertical stiffness, which is often considered the ‘first’ or ‘reference’ stiffness measure (21, 23, 25). It is a measure of resistance of the body to vertical compression after ground reaction force is applied (21, 23, 26). However, Leg stiffness (K_N) is not exactly the same as vertical stiffness. Vertical stiffness is a measure of body stiffness which refers to the whole gait cycle (i.e. stance and flight), whereas K_N refers to the lower limb. It relies on leg compression which can only be achieved during stance (22) . Therefore, this study used $K_{\mathbf{N}}$ as the measure of choice. It took into consideration resistance to change in leg length after internal or external forces were applied, as well as joint stiffness. It also considered resistance to change in angular displacement for flexion and rotation after the joint moments were applied (21, 23).

The stiffness in the human body involves the interaction of a number of anatomical structures (21, 22) and leg stiffness must be controlled by stiffness at the joints (24, 27-32).

The muscle power (P), leg power or muscle power described by some authors can be interpreted in different ways. Though muscle power is related, it is different from strength and is defined as the ability to perform muscular work per unit of time (*power* = *work/time*). To sum up, if strength is the ability to exert force, power is the ability to exert force quickly (*power = force x velocity*) (33). Leg power, measured by using the Nottingham Leg Rig, was correlated with gait speed, chair-rise time, and stair-climb time (34). Though leg power was shown to be predictive of self-reported disability in community-dwelling older women, the influence of muscle power on the physical performance of community-dwelling older people has yet to be demonstrated (35).

The aim of this study was to evaluate the MVC of the PFM in sportswomen with symptoms of stress urinary incontinence and verify if there was any association with maximal and submaximal K_N and P.

2. Methods

2.1. Study design and subjects

This is a cross-sectional study of Portuguese sportswomen, carried out between February and May 2019. The study was approved by the Research Ethics Committee of the University of Trás-os-Montes e Alto Douro (UTAD), Vila Real, Portugal (25/2017). All participants provided informed consent and conducted themselves according to the Declaration of Helsinki.

Forty-one women aged between 18 and 42 years were recruited. The inclusion criteria were sportswomen, sexually active, and if parous, to be more than 1 year postpartum, performing sports at least 3 days a week for more than 1year, and sportswomen with symptoms of stress urinary incontinence. The exclusion criteria were the inability to perform a correct PFM contraction or the inability to insert or maintain the vaginal probe due to pain or discomfort; combinations of multiple sports; irregularity of sport performance; surgical treatment of gynecological and urological illnesses; urinary tract infections and pelvic organ prolapse.

Each participant completed the socio-demographic questionnaire (demographic characteristics - age, obstetrics data, gynecological surgery or pathology; urine loss, during physical exercise; anthropometric characteristics - body weight, height and training characteristics – years of training, hours of training per day and frequency of training per week).

2.2. Clinical evaluation

2.2.1 Pelvic Floor Muscle

The physiotherapist evaluated the sportswomen's ability to perform a correct PFM contraction. This evaluation was performed at baseline. It was first carried out by digital palpation, where the index and middle fingers were introduced 2-3 centimeters into the vaginal introitus. The sportswomen is then asked to squeeze the fingers of the physiotherapist to overcome resistance and was told to do the same with the perineometer probe (36).

The manometry using the Peritron Perineometer 9300 (LABORIE Medical Technologies Canada ULC.). The first measure to be evaluated by manometry was *vaginal resting pressure* and the second was *MVC*. Measurements were obtained by the same researcher (TP), following standardized methodology. The vaginal probe was covered with a condom and the device was zeroed before insertion. The athletes were instructed to relax and contract the PFM. The lowest pressure value during rest was used as a measure of vaginal resting pressure. After zeroing the perineometer, the participants were asked to perform an MVC, hold it for 3 seconds, and the peak value was recorded. This procedure was repeated 3 times and the mean value recorded (37).

2.2.2. Leg Stiffness and Power

Protocol

The stiffness and muscle power measurement method of the present study has been validated in submaximal and maximal hopping conditions (26). It is simple, cheap and can be used in the field, as well as in laboratory conditions. This protocol was performed in laboratory conditions. Each sportswoman performed a warm-up by hopping intermittently for 5 minutes, in order to be familiarized with the hopping test routine for the two conditions.

The first condition was the sub-maximal, two-legged hopping test, which was performed allowing sportswomen to self-select their preferred frequency. Only hops within a self-selected frequency between 2 and 2,5 Hz were considered for analysis (38).

Each sportswoman was asked to hop two-legged on the top of the force platform for 10 consecutive hops. The first and the last hops was discounted for analysis.

The second condition was the maximal two-legged hopping test, which was performed asking athlete to maximize hop height and minimize contact time on the top of the force platform for 6 consecutive hops. The first and the last hops was discounted for analysis.

To avoid the influence of the upper-limbs movement, all the sportswomen performed each hopping test with theirs hands laterally positioned on their waist. All sportswomen performed the two tests barefoot in order to avoid the potential influence of the footwear.

The order of test conditions (sub-maximal two-legged hopping test or maximal two-legged hopping test) was randomized with a 2 minutes rest pause offer between conditions.

Measurement equipment

Ground Reaction Forces

Throughout the test, KN and P were measured and recorded using a force platform (type 9281b, Kistler Instrument AG, Winterthur, Switzerland), connected to an electronic amplifier (Kistler type 9861A) and mounted according to the manufacturer’s specifications. The force signal was linear (<0.5%) over the range 0-10kN. The resonance frequency of the force platform was over 200Hz. The force signals were sampled at 500Hz using a 12-bit data acquisition board unit (Biopac MP-100) and collected on a personal computer.

Leg Stiffness calculations

The calculations for K_N were based on the model of the ground reaction force as a sine wave, where it is assumed that the area below the curve equals that of the impulse of the ground reaction force. After determining the peak reaction force and the vertical displacement during contact (ΔL), the vertical stiffness was calculated as shown below, where M was the total body mass, T_c the ground contact time and T_f the flight time (26):

$$K_N = \frac{M \times \pi \, (T_f + T_c)}{T_c{}^2 \left(\frac{T_f + T_c}{\pi} - \frac{T_c}{4}\right)} \quad \text{(in N x m}^{-1}\text{)}$$

The method is fully described in the appendix A.

Muscle power calculations

For this method, P was calculated from T_c and T_f measurements. The total vertical displacement (h) was calculated as the sum of the vertical displacements of the centre of mass during contact (ΔL, see appendix B) and during flight phases. It was then possible to determine the P of the propulsive phase by dividing the mechanical work, Mgh, where M was the body mass and g the gravitational acceleration, by the propulsive period, $T_c/2$ (26) (appendix B):

$$P = \frac{Mg^2}{T_c}\left(\frac{T_f{}^2}{4} + \frac{T_c(T_c+T_f}{\pi} - \frac{T_c{}^2}{4}\right) \quad \text{(in W)}$$

2.3. Analysis

The variables studied were characterized by the minimum, maximum, mean (M) and standard deviation (SD) values. Correlations between variables were studied using Pearson's correlation coefficient (R). A significance level of 5% was considered, meaning that correlations were considered statistically significant when the significance value was less than 0.05 ($p < 0.05$). Statistical analysis was performed using SPSS, version 24 for Windows.

3. Results

The sample consists of 41 sportswomen aged 18 to 42 years (M = 24.9, SD = 6.5), with an average weight of 60.5 Kg, an average height of 1.65 m and an average BMI of 22.1 kg /m^2. The values of the submaximal K_N range from 6532.7 to 28817.9 m (M = 14996.5, SD = 5686.8), the maximal K_N range from 2191.3 to 25603.8 m (M = 11290.1, SD = 5064.8), the submaximal P range from 233.6 to 1087.7 N (M = 572.3, SD = 217.6) and maximal P range from 723.1 to 1949.8 N (M = 1297.3, SD = 243.5). The average MVC is 66.5 mmHg with a minimum of 31.3 and a maximum of 133.3 mmHg (Table 1).

Table 1 - Characterization of the participants included in the study (n = 41).

	Range	**Mean (SD)**
Age (years)	18 - 42	24.93 (6.52)
Weight (Kgf)	48 - 78	60.51 (7.75)
Height (m)	1.56 - 1.76	1.65 (0.05)
BMI (Kg/m^2)	17.6 - 29.6	22.1 (2.6)
Submaximal K_N (m)	6532.7 - 28817.9	14996.5 (5686.8)
Maximal K_N (m)	2191.3 - 25603.8	11290.1 (5064.8)
Submaximal P (N)	233.6 - 1087.7	572.3 (217.6)
Maximal P (N)	723.1 - 1949.8	1297.3 (243.5)
MVC (mmHg)	31.3 - 133.3	66.5 (26.8)

BMI, body mass index; K_N, leg stiffness; P, muscle power; MVC, SD, standard deviation.

The results in Table 2 show that maximal and submaximal K_N values increase with increasing age, weight, height, and BMI - positive (r between 0.233 and 0.478) and significant ($p < 0.05$) or close correlations. There is statistical significance. Regarding maximal and submaximal P, correlations are positive and significant with weight and BMI (r between 0.462 and 0.529), indicating that P values are higher in heavier women with higher BMI. Correlations with MVC are not significant ($p > 0.05$) (Table 5.1.2).

Table 2 - K_N, P and MVC correlations with age, weight, height and BMI (N = 41).

	Age (years)	**Weight** (Kgf)	**Height** (m)	**BMI** (Kg/m^2)
Submaximal K_N (m)	**r = 0.478** **(p = 0.002)**	**r = 0.424** **(p = 0.006)**	r = 0.302 (p = 0.055)	r = 0.283 (p = 0.073)
Maximal K_N (m)	r = 0.288 (p = 0.068)	**r = 0.381** **(p = 0.014)**	r = 0.308 (p = 0.050)	r = 0.233 (p = 0.142)
Submaximal P (N)	r = 0.143 (p = 0.371)	**r = 0.462** **(p = 0.002)**	r = -0.002 (p = 0.991)	**r = 0.521** **(p < 0.001)**
Maximal P (N)	r = -0.136 (p = 0.398)	**r = 0.529** **(p < 0.001)**	r = 0.151 (p = 0.346)	**r = 0.505** **(p = 0.001)**
MVC (mmHg)	r = -0.053 (p = 0.742)	r = -0.149 (p = 0.351)	r = -0.280 (p = 0.077)	r = -0.006 (p = 0.970)

BMI, body mass index; K_N, leg stiffness; P, muscle power; MVC, maximum voluntary contractions.

The results in Table 3 show strong positive correlations between maximal and submaximal K_N (r = 0.759, p <0.001) and between maximal and submaximal P (r = 0.496, p = 0.001). Correlations between K_N and P values are close to zero and not significant, indicating the absence of a correlation between these variables.

Table 3 - Correlations between K_N and P (n = 41).

	Submaximal K_N (m)	**Maximal K_N** (m)	**Submaximal P** (N)	**Maximal P** (N)
Submaximal K_N (m)	-	-	-	-
Maximal K_N (m)	r = 0.759 (p < 0.001)	-	-	-
Submaximal P (N)	r = -0.038 (p = 0.815)	r = -0.037 (p = 0.818)	-	-
Maximal P (N)	r = 0.137 (p = 0.393)	r = 0.096 (p = 0.551)	r = 0.496 (p = 0.001)	-

K_N, leg stiffness; P, muscle power.

Table 4 and Figure 1 show the results of the correlations of MVC with K_N and P. Results show that MVC values decrease with increasing K_N: the correlation is significant with maximal K_N (r = -0.488, p = 0.001), but weak and not significant with submaximal K_N (r = -0.191, p = 0.233). In contrast, MVC values increase with increasing P values: the correlation is significant with submaximal P (r = 0.313, p = 0.046), but weak and not significant with maximal P (r = 0.104, p = 0.518).

Table 4 - K_N and P correlations with MVC (N = 41).

	Submaximal K_N	**Maximal K_N**	**Submaximal P**	**Maximal P**
MVC (mmHg)	R = -0.191 (p = 0.233)	R = -0.488 (p = 0.001)	R = 0.313 (p = 0.046)	R = 0.104 (p = 0.518)

K_N, leg stiffness; P, muscle power; MVC, maximum voluntary contractions.

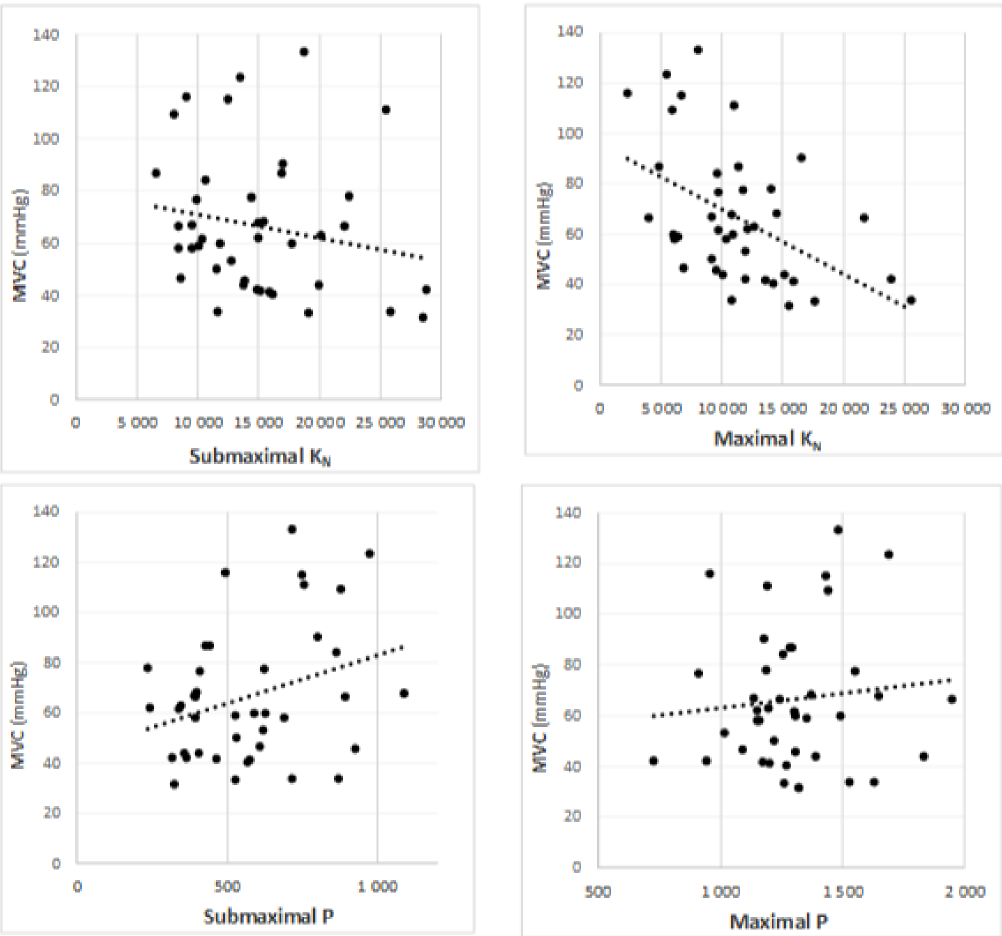

Figure 1 - Scatter plots of the relationship between MVC and submaximal K_N, maximal K_N, submaximal P and maximal P.

4. Discussion

This was the first cross-sectional study that evaluated the K_N and P correlations with MVCs. The results of this study demonstrate that a range and mean of submaximal and maximal K_N obtained from simple submaximal and maximal hopping were expected, meaning that the values of the submaximal K_N were greater than the maximal K_N (22).

According to table 2, the submaximal K_N value increases with increasing age. A study observed that when compared to young subjects, elderly subjects contacted the ground with a straighter lower extremity. They also bent their knees and ankles much less, resulting in about 30% less limb compression. This change in movement strategy resulted in approximately 60% greater leg stiffness in elderly subjects (39). The same authors later corroborated in another study that older people increase muscle pre- and coactivity when stepping downward to stiffen the leg in compensation for impaired neuromotor functions (40). In addition, the maximal and submaximal K_N and P values increase with increasing weight. Sartório et al (2004), observed that obese male subjects have a significantly higher lower limb maximal power output than female subjects (41). The maximal and submaximal P values also increase with increasing BMI. These results behave similarly to that of the study by Sartório et al (2004), with the BMI factor having a strong positive correlation with lower limb power output only in men, with the relationship being definitely less significant in women (41). It is important to note that leg stiffness during hopping represents a complex interaction of muscles, tendons, ligaments, cartilage and bones to resist the applied force (21), consequently a higher BMI was associated with a poorer performance (42).

Leg stiffness is a key parameter of data analysis and modeling of legged locomotion. In the scientific literature different methods of estimating leg stiffness can be found (43). In Table 5.1.3, the strong correlation obtained between maximal and submaximal K_N ($r = 0.759$, $p < 0.001$) and between maximal and submaximal P ($r = 0.496$, $p = 0.001$) showed that, although there are several methods, the present method could be used for stiffness measurement (26). These results suggest that for both K_N and P, when theirs values increase during a task at a certain intensity, they also increase when performing the motor task at other different intensities.

Furthermore, if K_N indeed predicts the risk of injuries as previously reported by Butler et al (21), K_N measurements should be included in standard test batteries for athletes to identify individuals at risk of injury (44).

Like what was reported in the study of Simeone et al, age, type of sport, number of hours of training, number of years an athlete is involved in sport, and the competitive level, may affect the athlete's performance and in turn these may be predictive factors of urinary disorders and SUI (45). Young athletes, particularly those who play high impact sports, are considered at a high risk for developing SUI (12, 15, 19). These high impact sports mostly include jumping.

Jumping movements have often been investigated to better understand and evaluate the lower limb mechanical properties. Vertical jump is the most widely used movement to assess the “explosive” or “ballistic” qualities of the lower limbs due to its simplicity. It has a very short duration (<0.5 s), a very high intensity (it is considered as one of the most “explosive” movements), and it has a high correlation with peak power output. Lower limb ballistic movement performance (jumping, sprint start, change of direction) is considered to be a key factor in many sport activities and depends directly on the mechanical capabilities of the neuromuscular system (46).

The results show that MVC values decrease with increasing K_N. In contrast, MVC values increase with increasing P values. To better understand how humans, regulate leg stiffness in hopping, numerous studies were investigating stiffness at the joint level. Indeed, leg stiffness as a general condition depends on the stiffness at the various joints of the leg, including the hip, knee and ankle joints. Stiffer joints will undergo smaller angular displacements during the contact phase, consequently reducing leg spring compression and thus increasing leg stiffness (47).

Several studies can support the results of the present study. The K_N values decrease with jump height (48) and this is positively associated with peak power outputs (49) and average power outputs (50), while power outputs are positively associated with higher strength performance during full body functional motor tasks (51). Laffaye et al (2005), concluded that K_N (mean value of 11.5 $k_N \cdot m-1$) decreased with jumping height.

The slight increase in vertical ground reaction force, as well as the large increase in leg compression, together resulting in the observed decrease in K_N with jumping height can be explained by the physiological and mechanical properties of the run-and-jump task (48). McBride et al (2010), observed that peak power was significantly correlated with jump height during both the static jumps series ($r = .6605$, $P< .0001$, power = 1.000 and the countermovement jumps series ($r = .6631$, $P < .0001$, power = 1.000) (49). This happened regardless all squat depths and loading conditions. Riggs et al (2009) describe how vertical jump height for both elite male and female beach volleyball players is closely associated with relative peak and average power outputs. Having a high power to weight ratio appears to be essential for athletes and should be taken into consideration when creating and monitoring elite beach volleyball athlete training programs (50). Finally, in their findings, Carlock et al (2004) state that vertical jumping peak power is strongly associated with weightlifting ability as well (51).

Training or rehabilitation programs should induce changes in force, velocity and P capabilities, according to both the mechanical demands of the targeted task and the sportswomen's actual muscle capabilities. To determine individual strengths and weaknesses in order to cater strength training modalities to individual needs, it is essential to know which mechanical capabilities lower limb muscles have to present to maximize ballistic push-off performances (52).

4.1. Limitations of the study

This study is the first to verify a correlation between K_N and P with MVC, therefore it has some limitations, particularly in the literature. We would argue that the literature is scarce, not enough to corroborate some results.

4.2. Clinical application

The use of this simple method as routine test provides interesting information to coaches or physiotherapists: individual maximal power and profile. This method allows for the follow-up of athlete muscle capabilities during a season or over several years, as well as a comparison between athletes, which can help to optimize training and individualize loads and exercise modalities in strength training (46). The simple method enables the measurement of leg stiffness from simple parameters: the body mass of the individual and contact and flight times. When compared to force platform methods, minimal data is stocked, data processing and calculation are greatly simplified, and no calibration is required. This method may thus be particularly advantageous for assessing leg stiffness in the field, as well as in laboratory conditions. In addition, the fact that this method is simple and inexpensive makes it accessible to most coaches and athletes (47).

5. Conclusion

In conclusion, the K_N and P measurement method has been validated in submaximal and maximal hopping conditions. Future research should apply maximal and submaximal K_N and P measurements in order to improve athlete performance, namely strengthening the PFM to support these preliminary findings and assessing the impact of this intervention.

Declaration of competing interest

The authors have no potential conflicts of interest to declare.

Appendices

Appendix A

The stiffness Calculation:

The stiffness is the ratio of the peak force to the displacement:

$$K = \frac{F_{max}}{z(0) - z\left(\frac{T_c}{2}\right)} = \frac{F_{max}}{-z\left(\frac{T_c}{2}\right)}$$

Using the expressions of:

F_{max}

$$F_{max} = Mg \times \frac{\pi}{2} \times \left[\frac{T_f}{T_c} + 1\right]$$

and

$z(T_c/2)$

$$z\left(\frac{T_c}{2}\right) = -\frac{F_{max}}{M}\frac{T_c^2}{\pi^2} - \frac{1}{2}g \times \left(\frac{T_c^2}{2}\right) + g\frac{T_c}{2}\left(\frac{T_c}{2}\right)$$

$$z\left(\frac{T_c}{2}\right) = -\frac{F_{max}}{M}\frac{T_c^2}{\pi^2} + g\frac{T_c^2}{8} \qquad (1)$$

The final equation is:

$$\frac{K}{M} = \frac{\pi \times (T_f + T_c)}{T_c^2 \times \left(\frac{T_f + T_c}{\pi} - \frac{T_c}{4}\right)}$$

As result, the stiffness can be calculated by measuring the contact time (T_c) and the flight time (T_g).

Appendix B

Calculation of the mean power:

$$P = \frac{Mg\,(h_{max} + z[T_c/2])}{T_c/2} \qquad (2)$$

Where h_{max} is the rising of the CM during the flight time, $z(T_c/2)$ represents the maximal displacement during the contact time as already calculated in appendix A.

During the flight time, $h_{max} = \frac{1}{8} g {T_f}^2$ (3)

according to the law of the free falling in gravitational field.
By substituting (1) and (3) in (2), the final equation is

$$P = \frac{Mg^2}{T_c}\left(\frac{{T_f}^2}{4} + \frac{T_c\,[T_c + T_f]}{\pi} - \frac{{T_c}^2}{4}\right)$$

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CHAPTER 6 – DYNAMIC CHANGES OF THE PELVIC FLOOR IN ELITE ATHLETES: ARE THERE DIFFERENCES BETWEEN SPORTS? A RESEARCH NOTE FROM THE FIELD

Pires, T., Pires, P., Moreira, H., Gabriel, R. Fan, Y, Moutinho, O., Viana, S., Viana, R. (submitted). Dynamic changes of the pelvic floor in elite athletes: are there differences between sports? A Research Note from the field. *Millenium Journal of Education, Technologies and Health.*

Abstract

Introduction: One of the functions of the pelvic floor muscles (PFM) is to support the pelvic organs and continence. This continence mechanism tends to change when PFM are exposed to high-impact exercises.

Objectives: To describe the dynamic changes in the pelvic floor (PF) in elite nulliparous athletes.

Methods: Translabial two and three-dimensional ultrasound was used to assess PF anatomy and function in athletes (n=8). This ultrasonography was performed after voiding and in the supine position, using a vaginal probe. The descent of the pelvic organs was assessed on a maximum Valsalva maneuver, whilst the volume datasets were acquired at rest, during maximum voluntary contraction (MVC) and during a Valsalva maneuver. The athletes performed each maneuver at least 3 times, with the most effective being used for evaluation.

Results: The bladder neck descent was 14 mm for the javelin thrower, being the highest value when compared to the remaining participants. Three athletes featured the rectocele (swimming, gymnastics and javelin throw) and 4 participants presented a paravaginal defect (volleyball, horsemanship, javelin throw and printer). The volleyball athlete had the highest value of the levator hiatal area in MVC value.

Conclusion: The athletes present minimal differences in the evaluated parameters. The sample is small to generalize the results, but there is a tendency for athletes of high-impact exercises to have a lower CMV value. Further studies are needed to corroborate these results.

Keywords: Levator ani; Maximal voluntary contraction; Pelvic floor function; Translabial ultrasound.

Abbreviations

2D: Two-dimensional
3D: Three-dimensional
LAM: Levator ani muscle
MVC: Maximal voluntary contraction
PF: Pelvic floor
PFM: Pelvic floor muscles
POP: Pelvic organ prolapse
PVU: Posterior vesico-urethral
SUI: Stress urinary incontinence
UI: Urinary incontinence

INTRODUCTION

The World Health Organization considers urinary incontinence to be a public health problem that mostly affects women and consequently compromises their quality of life. Some people still see this pathology as a natural consequence of age and adapt to the changes imposed by it. Nowadays it is known that it is not just a natural consequence of age, as it can also appear in young people, including nulliparous women and athletes.

1. THEORETICAL FRAMEWORK

Female athletes involved in sports that involve the musculoskeletal system can be susceptible to injuries. Recent studies show that young women involved in high impact sports are more prone to developing stress urinary incontinence (SUI), it is necessary, in most cases to strengthen the pelvic floor muscles (PFM) (Lourenco, Matsuoka, Baracat, & Haddad, 2018; Pires T, 2020; Pires et al., 2020).

The important role of the PFM is to support the pelvic organs, continence and childbirth (Karim, Begum, Ayub, Pervaiz, & Akhtar, 2019; Louis-Charles, Biggie, Wolfinbarger, Wilcox, & Kienstra, 2019). Continence is a complex mechanism, involving the coordination between the PFM, the urethra, the bladder and their supporting ligaments. This mechanism involves both striated (voluntary control) and smooth (involuntary) muscles (Bø, 2004b). Levator ani muscle (LAM) is the collective term used to describe the deep muscles of the pelvic floor (PF) and consists primarily of the striated muscles pubococcygeus, puborectalis and iliococcygeus (Brandão et al., 2015; Louis-Charles et al., 2019).

The female pelvic organs are grouped into anterior (bladder and urethra), central (vagina and uterus), and posterior (or anorectal) compartments. The spectrum of the PF dysfunction depends on the compartment involved and includes urinary incontinence (UI), fecal incontinence/anorectal dysfunction and pelvic organ prolapse (POP), occurring in varying combinations (Brandão et al., 2015). POP happens when there is a protrusion of one or more pelvic organs (the bladder, rectum, uterus, vaginal vault, bowel) through vaginal fascia, pressing into the vagina (Ying, Li, Xu, Liu, & Hu, 2012). POP can be defined as the following: cystocele, if it is from the anterior vaginal wall; rectocele, if it is from the posterior vaginal wall; central compartment: hysterocele and prolapse of the vaginal dome (Bernard T Haylen et al., 2016). When the posterior vesico-urethral (PVU) angle is to be evaluated, it is done at rest and the Valsalva maneuver; the levator hiatal area is, at rest, the Valsalva and Maximal Voluntary Contraction (MVC). The Valsalva maneuver, which is a forced expiration against a closed glottis and contracted diaphragm and abdominal wall, is routinely used to document downwards displacement of pelvic organs and demonstrate distensibility of the levator

hiatus. The MVC is the individual's maximum ability to contract the PFM. Recording a PF contraction at the time of prolapse assessment can serve many purposes, one of which is that it can be a teaching opportunity for visual biofeedback (H. P. Dietz, 2011).
The aim of this study was to describe the dynamic changes in the pelvic floor in elite nulliparous athletes.

2. METHODS

2.1 Sample

Original research, reporting the PF function by translabial 2D/3D ultrasonography in a sample of 8 athletes. In this research note, the sociodemographic and anthropometric data were collected using a structured questionnaire. The inclusion criteria were elite nulliparous athletes trained or qualified in a particular sport, between 18 and 30 years old. The exclusion criteria were the inability to perform a correct PFM contraction, combination of multiple sports and surgical treatment of gynecological and urological illnesses. All athletes were active in the first league of their various sports and at the time of testing had been training for a minimum of 5 years, having reached a national or international level of competition.

2.2 Data collection instruments and procedures

The sports included were: volleyball (1), swimming (n=1), karate (n=1), gymnastics (n=1), horsemanship (n=1), pentathlon (n=1), javelin throw (n=1) and sprinting (n=1). Ethical approval was obtained from the Ethics Committee of the Hospital center of Trás-os-Montes and Alto Douro, Vila Real, Portugal (165/2018). All participants gave informed written consent. The evaluation and imaging were performed using GE Voluson 730 pro and were carried out by an experienced doctor, who did not have access to all the clinical information**.**
All athletes were imaged in a supine position, after voiding. Imaging was performed in the mid-sagittal plane with the angle of acquisition set at 90º. The posterior vesico-urethral angle was acquired at rest and during a Valsalva maneuver. The most effective of at least three maneuvers was used for evaluation. The descent of the pelvic organs was assessed during the Valsalva maneuver. The levator hiatus was measured at rest, during the Valsalva maneuver and MVC of PF.

2.3 Statiscal analysis

Sample characteristics (age and BMI) were described using mean±standard deviation. For the biometric indices, the value of each athlete is presented.

3 RESULTS

The results from the questionnaire indicate that all were asymptomatic for SUI or gynecological disorders. Eight international female league players, of different sports (age, 22.4±4.1 years and body mass, 20.7±1.9 kg) volunteered to participate in the study.

Concerning the 2D ultrasound, the findings were the following: the *PVU angle* measurements were similar, showing no difference between them, either at rest or Valsalva. Only the karate athlete has urethral hypermobility because her value during the Valsalva maneuver was 164.40º, although it was asymptomatic. The results of *bladder neck descent*, relative to the symphysis pubis on maximum Valsalva demonstrate that the most favorable value was in volleyball, with no movement/descent of the bladder, while the worst value was in the javelin throw (still this value is within normal). Three athletes presented a mild *rectocele*, javelin throw, gymnastics and swimming modalities (Table 1).

Concerning the 3D ultrasound evaluations: the area of the *levator hiatus* at rest, the Valsalva and the MVC were measured. At rest, the lowest value was in pentathlon and the highest value was in javelin throw. For the Valsalva maneuver, the javelin throw athlete showed the highest value and the pentathlon obtained the lowest value. Regarding the MVC, the lowest value was in gymnastics and the highest value was in volleyball. As for the *LAM* assessment, no participant showed LAM avulsion. A p*aravaginal defect* was detected in than half of the sample (n= 4). The athletes with the defect were in volleyball, horsemanship, pentathlon and sprinting (Table 1). There were no significant changes in normality with respect to the levator hiatal area and LAM avulsion (Figure 1).

TABLE 1 BIOMETRIC INDICES OF THE SUI, POP, LEVATOR HIATOS AREA, LAM AVULSION AND PARAVAGINAL DEFECT

	Assessment			Volleyball (n=1)	Swimming (n=1)	Karate (n=1)	Gymnastics (n=1)	Horsemanship (n=1)	Pentathlon (n=1)	Javelin Throw (n=1)	Sprinter (n=1)
2D	***SUI***	*PVU angle*	Rest (º)	143.07	105.21	129.52	108.89	133.95	116.00	142.90	117.50
			Valsalva (º)	140.00	122.19	164.40	141.15	126.29	127.00	160.87	146.16
		Bladder neck descent (mm)		0	5	10	0.17	7.15	4	14	6
	POP	*Cystocele*		No	No	No	No	No	No	No	No
		Rectocele		No	Mild	No	Mild	No	No	Mild	No
3D	***Levator hiatal area***		Rest (cm^2)	13.43	12.63	12.50	13.96	14.67	11.14	15.32	13.30
			Valsalva (cm^2)	13.33	15.36	17.33	15.60	14.65	11.65	19.26	13.48
			MVC (cm^2)	11.5	10.82	10.67	8.61	11.25	9.72	11.39	10.98
	LAM avulsion			No	No	No	No	No	No	No	No
	Paravaginal defect			Yes	No	No	No	Yes	No	Yes	Yes

2D, two-dimensional ultrasound; 3D, three-dimensional ultrasound; LAM, levator ani muscle; MVC, maximum voluntary contraction; POP, pelvic organ prolapse; PVU, posterior vesico-urethral; SUI, stress urinary incontinence.

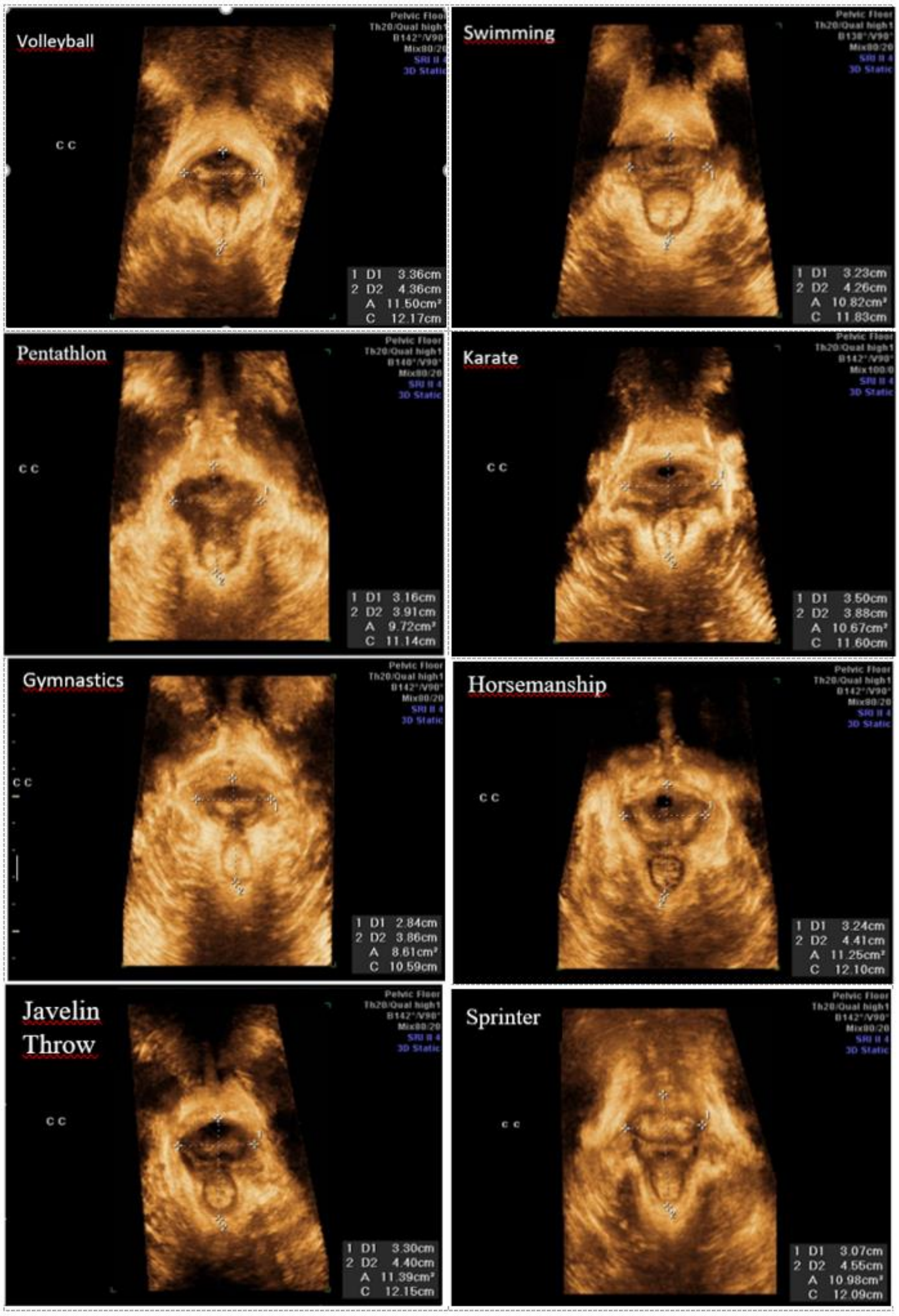

Figure 1. Measurement of maximum voluntary contraction (A) in the minimal hiatal dimensions.

DISCUSSION

Previous studies using 3D ultrasound imaging had evaluated functional and morphological parameters of young nulliparous athletes. Dietz et al (H. Dietz, Shek, & Clarke, 2005) found the hiatal area in their series of 52 nulligravid women to be 11.25 cm^2 at rest and 14.05 cm^2 during Valsalva. These findings are similar to this study. The dynamic assessment of the *LAM* was able to demonstrate that no participant presented *LAM avulsion*. Despite this, the javelin throw (high impact sport) athlete had a markedly increased *levator hiatus area* during a voluntary *Valsalva* maneuver. This might be explained by a higher awareness by high-impact athletes regarding the kinesthetics involved in high impact exercises, which can enable them to use task-specific muscles, as well as more abdominal strength, and the resulting increase in intra-abdominal pressure they are able to develop (J. Kruger, Dietz, & Murphy, 2007). The volleyball athlete had the highest value of the levator hiatal area in MVC, so she contracted the PFM less. As explained above, high-impact exercises can cause PF disorders, namely weakening of the PFM, which in turn can lead to SUI (Bø, 2004b; Bernard T. Haylen et al., 2010). This tends to be more prevalent in high-impact sports (Bø, 2004b; Pires et al., 2020), such as gymnastics, track and field, and some ball games (Mitchell, Haskell, Snell, & Van Camp, 2005). The prevalence of this study was an exception. SUI is mainly related to bladder neck hypermobility, PFM and pelvic ligaments which are weak or damaged (H. Dietz, 2004a, 2004b), as well as changes to the structure of the neuromuscular and connective tissues supporting the bladder neck and the urethra. If athletes continue to strengthen their PFM, urine leakage may never happen (Bø & Borgen, 2001; Eliasson, Larsson, & Mattsson, 2002; J. A. Kruger, Heap, Murphy, & Dietz, 2008). It is extremely important to have PFM training in these athletes, as it is advised for the prevention and treatment of SUI in several studies (Bø, 2004a; Hagovska et al., 2017). In order to better accomplish the MVC, the participants received information about the structure / function of the PFM, in addition to learning to develop awareness of them. This means that the athletes received assistance in contracting the correct muscle during the MVC, without contracting the other related muscles, such as the rectus abdominis, the thigh adductor and the gluteus maximus (accessories). Doing so would mean a considerable decrease in the contractile activity of the PFM (J. Kruger et al., 2007). SUI can interfere with athletes's participation in sport and fitness activities, consequently affecting their health, self-esteem and well-being (Bø, 2004b).

Two-dimensional (2D) ultrasonography has been one of the tools used to assess anatomical changes in the mobility of the pelvic organ of women suffering from SUI and POP (H. P. Dietz, 2011; H. Dietz, 2004a). The findings showed that the *PVU* angle at rest shows no significant changes. The findings during the Valsalva maneuver, demonstrated one participant (karate) had parameters compatible with urethral hypermobility. Although karate is considered a moderate impact sport (Mitchell et al., 2005), in fact the athlete mentioned that running, a high impact sport (Mitchell et al., 2005), is also part of her daily training, which may justify these results. Women with SUI commonly (or high impact sports) show an increase in bladder neck mobility and a descent below the level of the symphysis pubis during the Valsalva maneuver. Dietz et al (H. Dietz, Eldridge, Grace, & Clarke, 2004) noted that the high-impact, frequent intense training (HIFIT) nulliparous women group showed a considerably higher mobility of the bladder neck, as well as in the levator hiatal area than the control group. However, most of the HIFIT women were asymptomatic for UI, as observed in our study as well. The *bladder neck descent* measurements were the highest in the javelin throw (even though, within normal ranges). The remaining measurements were within the normal parameters (H. Dietz, 2004a). There is no definition of ‘normal’ for bladder neck descent, although a cut-off of 2.5 cm has been proposed to define hypermobility (H. Dietz, 2004a). Urethral mobility as a measure of urethral support, focuses mainly on the bladder neck (H. P. Dietz & Bennett, 2003; Pirpiris, Shek, & Dietz, 2010). There is minimal information available on the mobility of the remainder of the urethra, which we believe is important to understand urethral support and the pathophysiology of SUI and urodynamic stress incontinence (H. Dietz, 2004a). According to Dietz et al (H. Dietz, 2004a), the retrovesical (or posterior urethrovesical) angle usually opens to up to 160–180◦, from a normal value of 90–120◦. Such a change in the retrovesical angle is often (but not always) associated with funneling. Three athletes (swimming, gymnastics and javelin throw) demonstrated a mild *rectocele*, but were asymptomatic for clinical symptoms of *POP*. The women with increased pelvic organ descent are usually associated to having ‘weak’ PFM. There is a known correlation between hypermobility syndrome and some connective tissue disorders, including an increased risk for POP (Pirpiris et al., 2010). These differences may be explained by the differences in the connective tissue itself or the muscle biomechanics, which may have originated before or after the high-impact training (J. Kruger et al., 2007).

CONCLUSIONS

Although the sample is very small for large conclusions, there is a tendency for high-impact sports to suffer more changes in PFM, namely weak MVC that may lead to the appearance of SUI. Overall, the differences among athletes were not significant.

Future research with a larger sample of high-performance athletes is necessary to explore whether they present similar results after the intervention.

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CHAPTER 7 – GENERAL DISCUSSION

General discussion

The main aim of this thesis was to study the effect of PFMT protocol and understand whether its interventions can support athletes with SUI in their disease management and impact significantly on health-related outcomes. The body of evidence on PFMT protocol for athletes was updated regarding its effectiveness, methodologies and athletes' adherence and satisfaction with the available technologies, including access to an APP intended for athletes. Also, the impact of a PA - focused behaviour intervention combined with pelvic rehabilitation of athletes with SUI was researched. In this chapter, the results from the studies that have supported this thesis are integrated and discussed in light of the most updated literature and a description of the general limitations is provided, hoping to contribute to improve the knowledge in the field of prevalence and treatment of SUI.

Effectiveness of Pelvic floor muscles training

The need to alleviate this major public health problem, UI (1), is expanding dramatically to reduce health-related costs while increasing patient involvement in their own care and minimizing possible harm, notably with respect to health, performance, and QoL of these athletes. The study presented in **Chapter 2** found that there are still a limited number of studies, notably RCTs of prevalence of UI in high-impact sports, most of them published in the last five years which emphasise the novelty of this type of prevalence and intervention. This study found that the prevalence of UI among female athletes was 25.9% and when analysed only SUI, the prevalence was 20.7%. The prevalence in high impact sports was 25.6%, the highest being in volleyball, with 75.6%. However, meta-analyses conducted in this study showed that there is still no clear indication that PFMT improves health-related outcomes and reduces healthcare utilisation in SUI, because the samples of the studies included were relatively small and the number of ones pooled for analysis was limited for each outcome. These limitations highlighted in this study emphasise the idea that the role of PFMT is yet inconclusive. This study supports the current recommendations of treatment and prevention of SUI (2-4). Nevertheless, further research is needed to assess the effectiveness of PFMT. Other methodological limitations may also have accounted for the results found in this study. These are comprehensively described in **Chapter 2**, but the one major limitation was the variability of outcome measures and heterogeneity of study designs. Some studies used one single measure as main outcome, while other studies combined several measures. In some studies, only the questionnaire was used to assess the prevalence of SUI symptoms. It correlates very well with urodynamic tests or other urogenital diagnostic (e.g. pad test, voiding diaries) (5). Further clinical trials studies should be performed, including more reliable diagnostics, to analyse the prevalence of UI.

In conclusion, PFMT has the potential to help athletes with symptoms of urine loss, without the need of face-to-face contact with healthcare services, thus leading to less costly interventions. This could also promote interactivity between athletes and healthcare professionals and help decentralise healthcare by extending its access to regions where healthcare professionals are scarce. However, evidence to support this type of intervention is still limited and further work needs to be conducted before it can be incorporated into clinical practice.

Behaviour change towards improved performance and QoL of athletes with SUI

Scientific advancements have increased the opportunities to improve performance and QoL of athletes with SUI symptoms. **Chapter 4** assessed the effects of PFMT on elite female volleyball athletes and if this is an effective therapy for SUI. This was the first randomized controlled trial which evaluated MVC and Pad test on elite female volleyball athletes. Findings suggest that this intervention in EG is feasible and enhances athletes' MVC and decreases the loss of urine. Differences between groups may be explained by the efficacy and duration of the PFMT program (16 weeks). This protocol has been applied with varied degrees of success in interventions conducted with other populations, health behaviours, and different duration. In this study, the high prevalence of SUI may be justified by the association between urine leakage and PFM strength, as volleyball is a high-impact sport, these exercises may cause PFM disorders due a frequent increase in intra-abdominal pressure or by the reaction to ground forces (6). The prevalence of SUI in CG increased. The reason for this may be because the CG did not receive any teaching, prevention, or treatment to strengthen the PFM. Once again this reinforces the idea that SUI is mainly related to bladder neck hypermobility for weakness or damaged PFM, pelvic ligaments and laxity of the urethral fascia (5), that is, structural changes of the neuromuscular and connective tissues supporting the bladder neck and urethra (7). If athletes continue without strengthening the PFM, the loss of urine may be maintained or even increase. **Chapter 4** also assessed the QoL. In this study, the athletes did not have a poor quality of life. These athletes by completing the KHQ felt that they did not lose urine, perhaps because this self-declared questionnaire does not always correspond to reality, since it is subjective. With the evaluation of the pad test, it was found that in fact some lost urine, and this is an objective and more reliable evaluation. The sample is also small, which makes it impossible to generalize results. However, SUI can be a barrier to women's participation in sport and fitness activities and, therefore, it may be a threat to women's health, self-esteem, and well-being (8). The costs associated with the addition of the PFMT were relatively small as well as the time needed by the physiotherapist to provide support. In the discussion of **Chapter 3**, it is also known that this intervention can be implemented in various women's teams, without a need for significant additional costs or human resources and SUI may no longer be an obstacle for these athletes. Further research is needed to study the cost-effectiveness of this PFMT protocol. Therefore, the hypothesis of changing one's lifestyle after the intervention translates into better measures related to improving quality of life (9). Future research should apply a PFMT protocol.

Chapter 5 was the first cross-sectional which evaluated the K_N and P correlations with MVC. The results of this study demonstrate that a range and mean of submaximal and maximal K_N obtained from simple submaximal and maximal hopping were expected, that is, the values of the submaximal K_N were greater than maximal K_N (10). Furthermore, if K_N indeed predicts the risk of injuries as previously reported by Butler et al (11), K_N measurements should be included in standard test batteries for athletes to identify individuals at risk of injury (12). The results show that MVC values decrease with increasing K_N. In contrast, MVC values increase with increasing P values. Stiffer joints will undergo smaller angular displacements during the contact phase, consequently reducing leg spring compression and thus increasing K_N (13). The MVC values compared to K_N and P have an inverse relationship. Therefore, the hypothesis that an increase in P may lead to an increase in MVC was possible to demonstrate. One possible explanation is that MVC values may be associated with higher P during maximal exercise execution. If training is prepared to increase P, will we be able to increase MVC? This hypothesis should be explored in future research. Findings suggest that this intervention is feasible and may improve the athletes' urinary symptoms, because increasing P can increase MVC and, in turn, decrease urine loss. Training or rehabilitation programs must induce changes in force, velocity, and P capabilities according to both mechanical demands of the targeted task and actual athlete's muscle capabilities. In order to determine individual strengths and weaknesses and then individualize strength training modalities, it is essential to know which mechanical capabilities lower limb muscles have to present to maximize ballistic push-off performances (14).

In **Chapter 3,** an important result found was that the practice of high-impact activities decreases QoL (compared to low-impact activities). Several studies point to high impact sports, which are one of the most demanding factors of SUI (15-19). In fact, the prevalence rates of SUI in high-impact sports athletes remain high (15, 20-23). An interesting result was that the weekly time of PA is associated with a better QoL in symptomatology. Pucci et al concluded, in their systematic review, that there is a positive association between PA and QoL, which varies according to the domains of QoL assessed (24). Vuillemin et al corroborated that the PA recommended levels was associated with higher health-related QoL scores (25). QoL is a conscious cognitive judgment of satisfaction with one's life, within a sociocultural context regarding their aims (25). However, many athletes considered SUI to have implications on QoL and sports performance as they use strategies to hide the leakage and hide it from health professionals, believing that UI is common (23, 26-27). **Chapter 6** establishes that further research with larger samples and follow-up assessments is warranted to support these findings and assess the long-term impact of this intervention in SUI.

Limitations

The present thesis has some important limitations which should be considered when interpreting the results. First, the systematic reviews presented in **Chapter 2** were restricted to studies published in English and Portuguese. Studies published in other languages could also be relevant for the scope of these reviews. Second, the keywords used in the search strategy did not include all terms, such as “High-impact” and “Pelvic Floor Muscle”, which may have reduced the number of relevant papers found. Third, the studies included in the systematic reviews were not exactly the same due to their study design (i.e., only randomised and non-randomised controlled trials entered in Study 1), therefore, a direct relationship between the outcomes prevalence and PFMT in high-impact sports could not be investigated in all. In addition, research was conducted based on the last 10 years which also limited the number of studies. Further research should explore the impact of the methodologies in the effectiveness of PFMT in SUI.

In **Chapter 3,** one limiting factor was that the athletes were not all nulliparous and could be more homogeneous. Findings from the present study must be interpreted considering its limitations. Future research is warranted, namely randomized Controlled trials.

Chapter 4 included small sample sizes and most participants were in mild and moderate SUI grades. Therefore, the generalisability of results is limited. Further studies with larger samples and different SUI grades are needed to understand which athletes are most likely to benefit from the PFMT protocol. Another limitation of this chapter concerns the final assessment: the KHQ should have been applied again. Future research is needed to explore whether athletes with lower levels of baseline performance show similar (or not) outcomes after the intervention. The evaluation of the results was not concealed in **Chapter 4** because all measures were administered by the same researchers who implemented the intervention. Finally, the PFMT protocol had positive effects, resulted in decreased urine loss, and increased PFM strength in EG immediately after the intervention. However, it is unknown whether these findings were sustainable as the short- and long-term effects were not assessed. More research on the sustainability of the results is needed.

Chapter 5 is the first to verify a correlation between leg stiffness and P with MVC, as such, there are some limitations, particularly in literature which is scarce, and we would say that it is not enough to corroborate some results.

Chapter 6 included a small sample. There should be at least one CG so we can get a comparison with one EG. Although the aim was to compare the modalities with each other to try to understand which of the activities with the high or low impact would have a greater or a less significant change in the Pelvic Floor. However, the sample is still small, since 1 athlete for each modality is insufficient to be a study to yield conclusive results.

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CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH AND CLINICAL PRACTICE

Conclusions

This thesis contributes to further understanding of the importance of PFMT in treatment and prevention of athletes with SUI.

Findings provide evidence of the effectiveness of PFMT (**chapters 2 and 4**). The PFMT can be adjusted to ensure its suitability for the target population.

Chapter 3 revealed a positive association between MVC and weekly time of PA in QoL. Age, BMI, and high impact sports appear to be risk factors of QoL in female athletes with urinary symptoms.

Chapter 5 provides important recommendations for the development and implementation of future PFMT interventions. It was also concluded that a force platform has the potential to support the athlete by reliably tracking, storing and providing feedback on an individual's P levels and as a training plan P may lead to increased PFM strength.

Chapter 6, the 2D/3D-dimensional ultrasound is fundamental to assess the Pelvic Floor, whether it is muscles, ligaments, joints or even the anatomical structure itself and make a complete diagnosis of SUI. The sample of the included study was relatively small. This limitation, highlighted in this study, emphasises the idea that high-impact sports predispose SUI is yet inconclusive.

Further research with larger samples and follow-up assessments is warranted to support these findings and assess the short- and long-term impact of this PFMT protocol in female athletes to decrease the prevalence of SUI in high-impact sports.

Recommendations for future research and clinical practice

This chapter presents the main recommendations for future research as well as implications for clinical practice.

Findings from **Chapters 2 and 4** showed that there is still evidence, but not as robust as that to support PFMT protocol interventions in SUI and further work needs to be conducted before it can be incorporated into clinical practice. Recommendations for future research are the following:

Studies should be conducted with larger samples, higher methodological quality (e.g., multicentre randomised controlled trials) and longer observation periods:

- There is a need to identify clinical indicators of exacerbations and develop algorithms to help recognise athletes' QoL and performance. This information would be valuable to develop prevention and treatment for SUI.

- The PFMT should be tested and tailored to users prior to its implementation and more training sessions should be provided to athletes to improve their adherence. In addition, there is an urgent need to identify the type of athletes most likely to benefit from these interventions.
- The PFMT protocol should provide information on how behaviour change is encouraged.
- An assessment of athletes' behaviour change and its determinants should be conducted along with the teaching of the PFMT protocol and encouragement by the professionals who accompany the athletes.
- Outcome measures should be similar across studies and reported in a format that can be further pooled into meta-analysis and easy to replicate with any professional or athlete in need.

Findings from **Chapters 3, 5 and 6** suggest that a behavioural intervention (by health professionals and the athlete to reduce SUI risk factors) focused on PA during and after pelvic rehabilitation. It can be used to support athletes in achieving a more active lifestyle by helping them increase their self-esteem and daily performance. Nevertheless, more research is needed before it can be routinely used in clinical practice, specifically:

- The intervention should be implemented in larger samples with follow-up assessments to determine its short- and long-term impact in SUI.
- There should also be a look at whether athletes with lower performance at baseline present (or not) PA improvements after the intervention similar to those with higher performance.
- The role of the group as an additional stimulus for athletes' behaviour change should be investigated.
- It seems worthwhile to investigate whether general guidelines for the recommended minimum amount of PA for adults are also suitable for athletes with SUI and lead to health-related benefits.
- Finally, the (modifiable) determinants of PA behaviour in athletes with SUI should be identified to develop more effective interventions and, ultimately, provide guidance to the international health policies and action.

Appendices

Appendix 1 – List of publications

List of publications

Publications in Peer-Reviewed Journals

Citations: 0 [IF: 1.858]	**Pires T**, Pires P, Moreira H, Viana R. (2020) Prevalence of urinary incontinence in high-impact sport athletes: a systematic review and meta-analysis. *Journal Human kinetics*.
Citations: 3 [IF: 2.132]	**Pires T**, Pires P, Moreira H, Gabriel R, João P, Viana S, Viana R (2020). Pelvic Floor Muscle Training in Female Athletes: A Randomized Controlled Pilot Study. *International Journal of Sports Medicine*. doi:10.1055/a-1073-7977
Citations: 0 [IF: 2.000]	**Pires T**, Pires P, Moreira H, Gabriel R, Viana S, Viana R. (2020). Assessment of pelvic floor muscles in sportswomen: quality of life and related factors. *Physical Therapy in Sport*.

Abstracts in Conference Proceedings

[ISSN 1646-107X, eISSN 2182-2972]	**Pires T**, Pires P, Pires S, Moreira H, Viana R. (2019) Urinary Incontinence in female athlete. *7 th International Symposium on Strengh & conditioning.* 7º Simpósio Internacional de Força & Condição Física, 17-18 Março, Vila Real, Fortaleza.

Appendix 2 – Abstracts in Conference Proceedings

Conference Paper

Urinary Incontinence in female athletes - A Systematic Review

December 2019 · Motricidade

Conference: Proceedings of the 7th and 8th International Symposium on Strength & Conditioning. Motricidade, 15(2-3), 1-48. · Volume: 15

Project: Stress urinary incontinence

Telma Pires · Patricia Maria Pires · Maria Helena Moreira · Rui Viana

Aims: The aim is to procide systematic review of the literature of Urinary Incontinence (UI) and participation in sports and reviews the prevalence, incidence, treatment, prevention, evaluation, high-impact and risk factors in female athletes. **Methods:** A literature research was conducted in the PubMed / Medline, EMBASE, B-on and PEDro, with publishing dates ranging from january 2008 to december 2017. Limitations were humans, female, English and athletes. The sample had a diagnosis of UI based on subjective perception (symptom) and on perineometer, measured the Maximum Voluntary Contraction (MVC) of the Pelvic Floor Muscle (PFM). The participants were female nulliparous aged between 18 and 60 years. The assessment of methodological quality was performed based on the Grading of Recommendations, Assessment, Development and Evaluations (GRADE). All interventions included some form of exercise – PFM Training. **Results:** Eleven studies totalling 1301 athletes. The prevalence of UI was high, namely Stress Urinary Incontinence (SUI). In the five studies that studied the prevalence, the mean of this was 48,3% of SUI. The studies that evaluated MVC, the results were better in nonathletes (6.73 mmHg) than in basketball (3.65 mmHg), volleyball (4.38 mmHg) and handball (5.55 mmHg). The MVC increased after a training program (one study the values increased from 73.3 mmHg to 89.8 mmHg and in another went from 3.3 mmHg to 4.2 mmHg). The loss of urine decreases (45,5% in experimental group and 4,9% in control group). **Conclusion:** High prevalence of UI in young athletes, particularly when practising high-impact sporting activities. MVC is decreased in female athletes compared with nonathlete. A lower MVC correlates with increased symptoms of urinary incontinence and pelvic floor dysfunction. Training programs increased PFM strength, were effective to reduce UI. The results could be used to raise awareness and to alert athletes of the need to establish preventive strategies for UI.

Keywords: High-impact, sports, exercises, female athletes, pelvic floor muscle, stress urinary incontinence.

Revista de Saúde Pública, 48 (special issue), 137 (2014)

Appendix 3 – Ethical approval

UNIVERSIDADE DE TRÁS-OS-MONTES E ALTO DOURO
Comissão de Ética da UTAD

Parecer da Comissão de Ética N:	25/2017
Data:	21.06.2017
Assunto:	Doc 19/CE/2017 Projeto tese de doutoramento " Efects of pelvic floor muscles training on prevention and treatment of stress urinary incontinence in athletes"
Requerente:	Telma Pires/Coord: Rui Viana; Helena Moreira

A Comissão de Ética constata que a participação no estudo é voluntária, que as participantes podem desistir a qualquer momento e que a investigadora assegura às participantes a confidencialidade dos dados. Contudo verifica-se que existem campos nos formulários que permitem a identificação das atletas participantes:

1. Nome, profissão e número de telemóvel no questionário sociodemográfico;
2. Nome da participante na escala de Broome.

Além disso não é mencionado na documentação apresentada quem executará os exames de avaliação por palpação vaginal e por manometria.

A CE solicita portanto que todos os campos que permitam a identificação das participantes sejam retiradas dos questionários e que sejam identificados quais os técnicos competentes que irão efetuar os supra mencionados exames.

Dado que o presente parecer acompanhará a submissão do projeto de tese aos órgãos competentes da Escola, a CE declara que não se opõe ao início dos trabalhos de Doutoramento. No entanto, esses trabalhos estão condicionados à não realização de qualquer procedimento/ação com as atletas, enquanto não for aprovada pela CE uma versão reformulada da presente proposta (de acordo com o exposto acima).

O Presidente da Comissão

Pedro Miguel Mestre Alves da Silva

REPÚBLICA PORTUGUESA
SAÚDE

SNS SERVIÇO NACIONAL DE SAÚDE

chtmad

Exmº(a). Senhor(a):

Telma Filipa Rodrigues Pereira Pires
Aluna do 3º. do Ciclo de Ciências do Desporto

UTAD

ASSUNTO: ***Projeto de investigação***

V/ REFERÊNCIA

Após parecer emitido pela Comissão de Ética em reunião de 18.04.2018, o Conselho de Administração em 26.04.2018, autorizou o protocolo de recolha de dados que integra o projeto intitulado: Effects os pelvic floor muscles training on prevention and treatment os stress urinary incontinence in athetes, bem como se responsabiliza pelas taxas moderadoras da ecografia pélvica, a ser efetuada nas atletas de Elite integradas no projeto de investigação.

Com os melhores cumprimentos,

Vila Real 26.04.2018

Doc nº. 165/2018

O PRESIDENTE DO CONSELHO DE ADMINISTRAÇÃO

João Oliveira

Centro Hospitalar de Trás-os-Montes e Alto Douro E.P.E
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Appendix 4 – Informed Consent

Universidade Trás-os-Montes e Alto Douro

desporto utad

CONSENTIMENTO INFORMADO, LIVRE E ESCLARECIDO PARA PARTICIPAÇÃO EM INVESTIGAÇÃO de acordo com a Declaração de Helsínquia[1] e a Convenção de Oviedo[2]

Por favor, leia com atenção a seguinte informação. Se achar que algo está incorreto ou que não está claro, não hesite em solicitar mais informações. Se concorda com a proposta que lhe foi feita, queira assinar este documento.

Título do estudo: Estudo ecográfico do pavimento pélvico de atletas de elite, de várias modalidades.

Enquadramento: No âmbito da tese de doutoramento da aluna, Telma Filipa Rodrigues Pereira Pires, da Universidade de Trás-os-Montes e Alto douro (UTAD), sob a orientação do Dr. Rui Viana e coorientação da Dr.ª Helena Moreira, surgiu este estudo, que vai ser aplicado na população estudantil, do curso de Ciências de desporto da UTAD.

Explicação do estudo: A sua participação remete-se á avaliação da contração voluntária máxima, através do perineómetro (avaliação a realizar nas instalações da UTAD, sob a responsabilidade da autora do projeto de investigação), preenchimento de um questionário, acelerometria e uso de uma plataforma para avaliar o impacto.

Condições e financiamento: Não haverá pagamentos de deslocações, nem materiais. O financiamento será assegurado pelo investigador.

A sua participação será voluntária e assenta na gratuitidade e altruísmo. Tem o direito de recusar a sua participação no estudo a qualquer momento, sem que daí advenha qualquer prejuízo para si. Este estudo mereceu o parecer positivo da Comissão de Ética da UTAD.

Confidencialidade e anonimato: É garantida a confidencialidade, promete-se anonimato (não havendo registo de dados de identificação) e os dados obtidos serão unicamente utilizados neste estudo.

Um sincero agradecimento pela sua participação, disponibilidade e dedicação a este estudo.

Telma Pires (investigador principal)

Fisioterapeuta na Clínica de reabilitação física, Fisimagna Lda.

Contactos: 936972003 ou telmafilipapires@gmail.com

Assinatura: --

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Declaro ter lido e compreendido este documento, bem como as informações verbais que me foram fornecidas. Foi-me garantida a possibilidade de, em qualquer altura, recusar participar neste estudo sem qualquer tipo de consequências. Desta forma, aceito participar neste estudo e permito a utilização dos dados que de forma voluntária forneço, confiando em que apenas serão utilizados para esta investigação e nas garantias de confidencialidade e anonimato que me são dadas.

Nome: ---

Assinatura: --- Data: ...... /...... /...........

ESTE DOCUMENTO É COMPOSTO DE 1 PÁGINA E FEITO EM DUPLICADO:

UMA VIA PARA A INVESTIGADORA, OUTRA PARA A PESSOA QUE CONSENTE

Sport Sciences, Exercise and Health Department, Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, Apartado 202, 5001-911 Vila Real, Portugal.