The status of pelvic floor muscle training for women

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Abstract

There is no consensus on the amount of exercise necessary to improve pelvic floor muscle (PFM) function. We reviewed the pathophysiology of PFM dysfunction and the evolution of PFM training regimens since Kegel introduced the concept of pelvic floor awareness and the benefits of strength. This paper also describes the similarities and differences between PFM and other muscular groups, reviews the physiology of muscle contraction and principles of muscle fitness and exercise benefits and presents the range of protocols designed to strengthen the PFM and improve function. We also discuss the potential application of new technology and methodologies. The design of PFM training logically requires multiple factors to be considered in each patient. Research that defines measures to objectively quantify the degree of dysfunction and the efficacy of training would be beneficial. The application of new technologies may help this process.

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Résumé

Il n'existe aucun consensus concernant la quantité d'exercice requis pour améliorer la fonction du muscle du plancher pelvien (MPP). Nous avons examiné la physiopathologie d'un mauvais fonctionnement du MPP et l'évolution des plans d'entraînement de ce muscle depuis que Kegel a introduit le concept de la prise de conscience du MPP et les avantages de son renforcement. L'article décrit également les similitudes et les différences entre le MPP et d'autres groupes musculaires, passe en revue la physiologie des contractions musculaires et les principes de bon fonctionnement musculaire et les avantages liés à l'exercice. Nous présentons aussi divers protocoles visant à renforcer le MPP et à en améliorer le fonctionnement, ainsi que l'application potentielle de nouvelles technologies et méthodologies. Le plan d'entraînement du MPP nécessite en toute logique la prise en compte de multiples facteurs selon les patients. Des études cherchant à définir les mesures à utiliser pour quantifier de manière objective le niveau de dysfonction et l'efficacité de l'entraînement seraient utiles. L'application de nouvelles technologies pourrait contribuer à cet objectif.

Introduction

There is a large body of evidence and broad consensus that health benefits are derived from higher levels of daily physical activity. In 2007,[1] the Center for Disease Control and Prevention (CDC) and the American College of Sports Medicine conducted a systematic review to provide comprehensive public health recommendations based on available evidence of the benefits of physical activity. For the first time, the recommendations included the addition of muscle-strengthening activities (Table 1).

Simply stated, the total amount of physical activity required is a function of the type, intensity, duration and frequency of the activity,[1] and depends on many factors, such as health status, body composition and how effectively and conscientiously an individual performs a specific activity. Moreover, it is well-recognized that it is difficult to standardize a pattern and protocol of exercise that would benefit a broad population.

These issues also apply in the context of pelvic floor muscle (PFM) health and training. The pelvic floor is made up of a group of muscles and connective tissue that extends as a sling across the base of the pelvis; it comprises two layers, the superficial perineal muscles and the deep pelvic diaphragm, and provides support for the pelvic organs, the bladder and elements of the spine. Pelvic floor dysfunction and secondary stress incontinence negatively affect many women, and as the population ages, more and more women will be affected and the cost of dealing with these issues will also increase.[2] The origins of PFM dysfunction are multifactorial, and are a consequence of human evolution, childbirth, lifestyle and aging. The principal function of pubococcigeus in four-legged animals is to wag the tail.[3] With the evolution to upright posture, two-legged gait and the demands of childbirth, the pelvic floor became vulnerable to forces that disrupt the integrity of the PFM and compromise the support these structures provide to the pelvic viscera.[4] Many other factors also negatively impact the function of the pelvic floor, such as constipation, a sedentary life, the effects of menopause and advancing age. The consequences include stress urinary incontinence (SUI).

The principal recommendation for the treatment of SUI, according to the First International Consultation on

Table 1. Recommendations for physical activity

- To maintain health, all healthy adults aged 18-65 need moderate-intensity aerobic physical activity for a minimum of 30 min on 5 days each week or vigorous-intensity aerobic activity for a minimum of 20 min on 3 days each week
- To increase muscular strength and endurance 8-10 exercises must be performed on 2 or more nonconsecutive days each week using the major muscle groups
- To maximize strength development, a resistance (weight) should be used that allows 8-12 repetitions of each exercise resulting in a volitional fatigue

Incontinence in 1998, is to increase PFM strength.[5] Therefore, it is important to identify management tools that are effective and cost-efficient. The literature contains a range of training routines and recommendations and describes a variety of outcome measures and tools used to measure PFM function. However, there is no consensus on the optimal regimen to maintain pelvic floor function or remediate dysfunction and associated stress incontinence. This article reviews the pathophysiology of PFM dysfunction and the evolution of PFM training regimens. It also discusses the different protocols designed to strengthen the pelvic floor muscles and improve function and concludes with a summary of the new technologies to evaluate PFM dysfunction and quantify the degree of dysfunction and the efficacy of training regimens. We trust this information will help health professionals tailor their programs for their patients and to encourage more research in more scientific approaches to pelvic floor training.[6]

Physiology of muscle contraction

Muscle tissue comprises over a third of the human body's mass and is the principal site of energy consumption. Adequate supply of oxygen, adenosine triphosphate (ATP) and nutrients are required for contractile function. In health, the properties of a functional microcirculation enable muscle to balance oxygen supply and demand and influence local blood flow. In the short term, the greater the metabolic rate the higher the blood flow; in the long term, there is an increase in the size and number (angiogenesis) of blood vessels supplying the muscle. The ability of skeletal muscle to sustain contractile activity is correlated with the capacity of aerobic-oxidative energy metabolism[7] and depends on the type of muscle fibre (slow fibre type I or fast fibre type II). Most muscle groups contain an equal mixture of slow and fast fibres,[8] which have different metabolic characteristics. Type I twitch fibres contract slowly and generate energy for ATP via aerobic metabolism. Type II or fast twitch fibres predominantly generate energy anaerobically for a quick and powerful contraction, and exert 20% more force than slow-fibres.[8] Genetic factors and race influence the percentage distribution of type I or II fibres and this differs significantly among individuals, but studies have shown that specific training can convert type I to type II fibres, or vice versa.[9]

The velocity of muscle fibre contraction varies among the motor units: slow-twitch fibres, which generate less force, are recruited first. Once excitatory input increases, other motor units are recruited, and the stimulus activates fast-twitch fibres.[10] While muscular contraction plays an obvious role in locomotion, muscle tone and strength are required to maintain the integrity of the human organism and influence an individual's potential for loss of function and structural injury. Muscle contraction and energy consumption affect the basal metabolic rate and control of glucose metabolism, which are important in weight control. Muscular architecture and muscular power are correlated, but the quality of contraction is also important.[11] Skeletal muscle can generate about 3 to 8 kg of force per cm^2 of muscle cross section. The sarcomere, or the unit of contraction, contains molecules that modulate contractions and regulate assembly and disassembly in training or disuse.[12]

To initiate muscle contraction, a potential of action travels over the muscle that causes release of calcium ions from the sarcoplasmic reticulum and myosin-actin filament overlap.[9] Maximum muscular contraction occurs when tension is generated within the sarcomere by maximum overlap of actin and myosin filaments. The tension measured before muscle contraction begins is "passive tension" and "active tension" happens during movement. "Isometric contraction" occurs when the muscle is stimulated to contract at a fixed length (with no movement).[13] Muscle performance is optimal when contraction comes from the normal resting muscle length. Active tension decreases as muscle fibres stretch (e.g., beyond 150% of normal resting length), and is also low when the start point of the contraction is at around 70% of the normal resting length.[14]

The key biochemical elements of muscle function are oxidative capacity and the type of ATP isoform. Oxidative capacity is determined by the number of mitochondria and capillaries. Capillaries (with a source of adequate oxygen and metabolite supply during contractile activity) and fibres (with a high concentration of myoglobin) have a higher aerobic capacity and are, therefore, more fatigue resistant.[8]

Pathophysiology of pelvic floor muscle dysfunction

Pelvic floor muscle dysfunction affects muscle fibre length and contractile force. Distensile and stiff muscle fibres have a decreased ability to generate power. In women with SUI, Verelst and colleagues found a decrease in active force and stiffness in the pelvic floor. Patients whose muscular contraction occurs below the resting muscular length, as with overactive pelvic floor muscle (OPFM), experience muscular weakness and early time-to-fatigue.[15] To accommodate its supportive function, the PFM has a higher percentage of slow-fibres to maintain its tone and contraction, except during voiding and defecation. The delay velocity of contraction in type 1 fibres in a muscle, such as pubococcygeus, which has 70% slow-twitch fibres, explains why contraction is initiated by only a small number of fast-twitch fibres.[10] In incontinent women, the delay between stimulus and contraction of PFM is prolonged and slow-nerve conduction, suggestive of damage to the pudendal nerve, has been identified.[16]

Following denervation, there is atrophy of the denervated fibre, however, nearby healthy nerve fibres in PFM can stimulate reinnervation. In this case, the new fibre will assume the characteristics of the original one and change the morphologic nature of the tissue. In this way, following denervation, an original fast-twitch fibre can become a slow-twitch fibre, which affects the functional integrity of the pelvic floor.[17] Unlike nerves, muscles have considerable ability to self-repair and, with the appropriate stimulus, significant degrees of rehabilitation can occur. Exercise and effective pelvic floor training regimens play an important role in this process.

Although pelvic organ prolapse (POP) can follow pregnancy and childbirth, risk factors also include congenital or acquired connective tissue abnormalities, denervation and weakness of PFM.[2] Muscle fibre distention occurs as a consequence of POP and contributes to such patients achieving poor results with exercise and conservative treatment;[18] the causal mechanism may be that fibre distention prevents the proper filament overlap on initiation of muscle contraction. The relation between POP and PFM strength were studied by DeLancey,[19] who found a 43% incidence of reduced PFM strength and muscular atrophy among the group with POP, compared to controls.

The histological composition of the endopelvic fascia is heterogeneous (collagen, elastin, smooth muscle, blood vessels and nerves) and when this structural element of the pelvic floor is damaged rehabilitation through exercised alone has little impact. Six factors affect the development and maintenance of muscle mass: genetics, nervous system activation, environmental factors, endocrine influences, nutritional status and physical activity.[9] All are relevant to the structure and function of PFM, especially in women in the context of reproduction and menopause.

Principles of effective muscle training

To achieve effective function, patients should ensure that their pelvic muscles have strength (maximal force production), endurance and coordination. Also, the speed of contraction and metabolic efficiency of the muscle fibre will influence muscular performance.[8] To improve general muscle strength and power, sedentary, sick or elderly individuals are recommended to perform 1 to 2 sets of 8 to 12 preset exercise repetitions, with 8 to 10 exercises per session, at a frequency of 2 to 3 times per week.[13]

In the context of PFM training, there is no real differentiation between specific protocols for improving strength or endurance.[20] Generally, a muscle-training program should combine 3 main principles: overload, specificity and reversibility.[21]

The principle of overload means that the muscle targeted needs to perform more work than usual. This type of training enhances the number and size of mitochondria, and increases the activity of some aerobic and anaerobic enzymes, intramuscular glycogen content, and the number of capillaries and their surface area.[22] The muscle will also become hypertrophic and exhibit hyperplasia, even in muscles in the pelvic floor.[17] The training cycle achieves improvement in direct proportion to the physical work done up to an end point when fatigue occurs. Muscle fatigue is defined as "any exercise-induced reduction in the capacity to generate force or power output caused by the failure of the energetic process to generate ATP at a sufficient rate."[23] Verelst and Leivseth[24] considered a decline of 10% of the initial reference force as "time-to-fatigue" when investigating PFM function in continent and incontinent women and did not find a difference between them. In both groups time-to-fatigue occurred in 10.5 to 11 seconds of hold contraction at about 80% of maximal contraction values. This implies that it is necessary to overload the PFM muscle for a training program to be effective; however, fatigue may be the reason pelvic floor muscles fail and urinary incontinence happens. Consequently, fatigue during a rehabilitation program is probably contraindicated.[25]

The principle of specificity requires that the muscle must be trained with physical activity that replicates as closely as possible the functional movement required, (e.g., for a marathon athlete specificity requires running), at close to the maximal force or tension generated and progressive resistance weight training.[26] For the pelvic floor, the Kegel exercise meets the specificity requirement and is the only considered to improve PFM fibre function.[3,27]

The principle of reversibility implies that the benefits of the exercise are reversible if the patient does not incorporate the exercise into her daily routine.[26] It is, therefore, important that the patient maintain a regular exercise routine to sustain the SUI improvements achieved through PFM training. In the context of age-related muscle loss, however, training can only delay onset and is not ultimately preventive.[8]

The evolution of Kegel exercise

Arnold Kegel, a gynecologist from the University of Southern California, was the first author to talk about the PFM.[3,27] Since 1950, PFM exercises have been recommended to compensate for pelvic floor dysfunction, and limit prolapse and urinary incontinence. Kegel also generated interest about the impact of anatomical conditions on pelvic floor function. In 1963, Jones suggested that anatomic characteristics could influence the performance of PFM exercise.[28] With the introduction of biofeedback in 1984, the outcome of PFM training began to be evaluated and provided confirmation of the use of Kegel exercises in changing the PFM function.

In the 1990s, a series of randomized controlled trials assessed the effects of PFM training for the prevention and treatment of PFM dysfunction.[29-37] At least 2 systematic reviews evaluated PFM training using biofeedback measurement.[38,39] Although PFM training for urinary incontinence is considered Level 1 scientific evidence, Latthe, Foon and Khan identified weaknesses in the methodology of the studies; they claim that the studies lack the power to produce reliable results.[40] Major factors include the range of assessment methods and outcome parameters, and the heterogeneity of protocols available 60 years after Kegel's initial insight.

Review of such protocols reveals a range of recommendations for PFM contractions that extend from 5 to 200 per day (Table 2).[29-37] It is clear that there is no consensus on the amount of exercise required to improve PFM function. Over time, while different modalities and training protocols have been adopted, the most common approach is to use either PFM contraction exclusively, or in association with increased levels of overall physical activity.[41] Increased activity can benefit overall body strength and fitness, which intuitively would have a positive effect on SUI. The exact impact of such an improvement on the muscle groups in pelvic floor dysfunction has yet to be determined. Sapsford and Hodges recommend additional abdominal muscle training to optimize PFM strength.[42] Alternative methods, such as Pilates and yoga, to improve the strength of the body core musculature are considered effective.[43] Thus far, although these new techniques are popular, they lack substantive scientific investigation and validation.

Future directions

The "optimal" protocol for PFM training is still elusive. Physical therapists should discuss all the different elements that underlie a patient's pelvic floor weakness and dysfunction; this would allow the physical therapists to design an individual program for the patient. Clear instruction, motivation during therapy and scheduled follow-ups are essential for patients to experience sustained benefits of their exercise protocols.

Practitioners should consider the relevant aspects of PFM pathophysiology and the principles of effective muscle training described. They should also be prepared to explore new approaches and technology in assessing patients and evaluating the effectiveness of their training. In particular, a greater knowledge of exercise physiology and sports science may be applicable. There are ongoing investigations on the differences in the kinetics of mitochondrial oxygenation in individuals with and without athletic training.[44] It is also probable that a reduction of blood lactate accumulation

Table 2. Description of different design of exercise protocol

Study	Exercise protocol
Jones, 1963[28]	• PFMC 3 seconds hold, 3 second rest • Sets: 10 times each half an hour • PFMC 3 seconds hold, 3 second rest Shut off the urine flow during every voiding
Castleden, 1984[51]	• PFMC 4 or 5 every hours • 2 weeks of perineometer training • Orientation to interruption of micturition every day
Wilson, 1987[52]	• PFMC 5 seconds hold, 15 seconds rest • Sets: 3 per day
Henalla et al., 1989[29]	• 5 PFMC, with 5 seconds hold • Set per hour: 1 • About 80 VPFMC per day during 12 weeks • Weekly clinic visit
Hofbauer et al., 1990[30]	• Exercise program including PFMC, abdominal and hip adductor exercise • Twice a week for 20 minutes with therapist, and daily home program
Burns et al., 1993[31]	• 10 PFMC with 3 second hold, and 10 PFMC with 10 second hold • Progressed by 10 per set to daily maximum of 200 • Sets per day: 4 • Videotape describing exercise protocol
Wilson et al., 1995[32]	• 100 alternation fast (1 seconds) and slow (5 seconds) contractions daily
Bo et al., 1999[41]	• 8 to 12 high intensity (close to maximal) VPFMC, with 6 to 8 second hold and 3 to 4 fast contractions added at the end of each hold, 6 second rest between contractions • Sets per day: 3 • Body position: included lying, kneeling, sitting, standing; all with legs apart; subject to use preferred position • Audiotape of home training program • Weekly 45 minute exercise class to music, with PFMC in a variety of body positions, and back, abdominal, buttock and thigh muscle exercises
Aksac et al., 2003[34]	• 10 VPFMC, with 5 seconds hold and 10 second rest • Progressing at 2 weeks to 10 seconds hold and 20 second rest • Sets per day: 3
Yonn et al., 2003[35]	• PFMC for strength and endurance, taking 15 to 20 minutes per day • Strength: burst of intense activity lasting a few seconds • Endurance: 6 second holds progressed by 1 second per week to 12 second • Set per day: not stated
Borello-France et al., 2008[36]	• PFMC: 3 sets of 20 contractions (3 seconds hold) and 3 sets of 10 contractions (12 seconds hold) per session, twice a day

PFMC = pelvic floor muscle contraction; VPFMC = voluntary pelvic floor muscle contractions.

and the attenuation of muscle oxygen desaturation can be achieved when training regimens improve muscle oxidative metabolism.[45]

In the context of new technology, dynamic magnetic resonance imaging of the pelvic floor can now provide novel information on the anatomy and structural integrity of the components of the pelvic floor.[46]

Several investigators are using near infrared spectroscopy (NIRS) to monitor skeletal muscle function and the effects of exercise. It has been shown to be a reliable non-invasive measure for evaluating skeletal muscle oxidative metabolism and hemodynamics during and after exercise. Near infrared spectroscopy is being used for monitoring the effects of training programs on skeletal muscle performance.[47] It monitors changes in the concentration of oxygenated (O_2Hb) and deoxygenated (HHb) hemoglobin in tissue in real time,[48] and the data derived can be used to indicate the level of muscle fitness in athletes, non-athletes and patients with muscle dysfunction.[44,46-49]

Two parameters derived from NIRS data are of potential interest in PFM training: the recovery interval of muscle oxygenation and the muscle reoxygenation rate. The recovery interval of muscle oxygenation is the time needed for the recovery of O_2Hb concentration from the maximum level of deoxygenation at the end of exercise to the maximum level of reoxygenation during the post-activity rest period. The recovery interval reflects the influx of oxygenated arterial blood and continued oxygen utilization during the recovery period.[48] The muscle reoxygenation rate is calculated as the rate of increase in O_2Hb during the initial 3 seconds immediately after cessation of exercise. This reflects the velocity at which recovery starts after exercise and is directly related to muscle microvascular function.[49] Combined with a minimally invasive experimental NIRS technique that enables changes in pelvic floor oxygenation and hemodynamics to be monitored during Kegel exercise,[50] theses 2 measurement parameters could allow physicians to individually assess patients and quantify the efficacy of their training regimen.

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