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SYSTEMATIC REVIEW

Sport, physical activity, and urinary incontinence

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Objective. The objectives of this systemic review are to examine the troublesome problem of urinary leakage during competitive sport and vigorous physical activity, to look at how far this risk is modulated by regular exercise and by the maintenance of physical fitness, and in the light of the underlying patho-physiology, to consider the role of specific pelvic exercises and other practical approaches to managing this problem. **Methods.** The Ovid/Medline data-base was searched from1996 to July 2016. The MeSH term "Urinary incontinence" yielded 18,399 hits. Physical activity-related terms included "exercise" (113,883 hits), "physical exertion" (12,304 hits), "sports" (103,824 hits), "athletes" (5483 hits), or "physical fitness" (15,473 hits), for a total of 169,522 unique articles. Combining the 2 searches identified 243 articles. A review limited to human studies that provided abstracts, without restriction of language, identified118 relevant articles that dealt with athletes and military personnel with physically demanding work (34), physical activity and fitness (16), risk factors, particularly obesity (15), methods of diagnosis (11), methods of treatment (38) and incontinence in old age (5). This material was supplemented by a search of reference lists and personal files. **Results.** Leakage of urine during sport has commonly been determined by questionnaire, although there are objective methods of assessment such as weighing fluid accumulation in perineal pads Nine studies of athletes (mostly at the recreational level) and 2 reports on women with demanding military employment found rates of incontinence very similar to those anticipated in the general population of comparable age. However, 20 other studies of athletes, usually at a higher level of competition, and 2 further studies of military personnel noted that a high proportion of competitors were affected by leakage of urine of varying amounts during competition, with complaints being most frequent from participants in impact sports such as gymnasts, trampolinists, ballet dancers and runners. The increased risk of leakage persisted 10 yr after ceasing competition, but was not seen 20-30 yr later. In young adults, a high level of habitual activity sometimes involved impact activities, and thus an increase in the risk of incontinence, but the risk was reduced in older adults who were active and maintained a good level of fitness- perhaps because of control of obesity, a major risk factor for urinary leakage. The underlying pathology seems a weakness of the pelvic floor, and leakage can often be reduced by pelvic floor exercises; in some studies, the benefit of such treatment has been enhanced by biofeedback. **Conclusions.** Urinary incontinence is rarely discussed by those who are affected, but it is a cause of much social embarrassment, with anxiety reducing the performance of top athletes and reducing habitual physical activity in many older women. Symptoms can often be dramatically reduced by pelvic muscle training, and it is important to encourage affected individuals to persist with such treatment. **Health & Fitness Journal of Canada 2016;9(3):14-53.**

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Introduction

Urinary incontinence has been defined by the International Continence Society as a "complaint of any involuntary leakage of urine" (Abrams et al., 2002). Investigators commonly distinguish stress urinary incontinence, which is precipitated by physical exertion, sneezing or coughing from other types of urinary leakage, and this is the main focus of the present review. However, some authors maintain that repeated bouts of strenuous physical activity can also precipitate other forms of incontinence.

Data for U.S. adults over the period 2001-2008 showed an age-standardized prevalence of urinary incontinence of 51.1% in women and 13.9% in men (Dooley et al., 2008; Markland et al., 2011). The experience in several European countries has been similar (Hunskaar et al., 2004). The frequency and volume of leakage vary greatly, and because of personal embarrassment about the problem, incontinence tends to be under-reported to health professionals (Caylet et al., 2006). The response rate to one Italian questionnaire on incontinence was as low as 35.6% (Siracusano et al., 2003). Between 25 and 40% of average women have some urinary leakage at least once per year, and in 10% of females incontinence occurs as often as one per week (Bø et al., 2001; Buckley and Lapitan, 2010; Fantl et al., 1996; Hunskaar et al., 2003; Tennstedt et al., 2008).

Although urinary incontinence is sometimes considered a problem of the elderly, Sandvik and associates (Hannestad et al., 2000; Sandvik, 1984) found leakage of unspecified severity in 20-30% of Norwegian young women, rising to a prevalence of 30-40% in middle-age, and 30-50% in the elderly. A number of reports and review articles have suggested an increased risk in athletes (Jean-Baptiste and Hermieu, 2010; Lousquy et al., 2014; Popova-Dobreva, 2011), especially among participants in high-impact sports (Bø, 2004; Caetano et al., 2007; Goldstick and Constatini, 2014).

Stress incontinence is in itself often a social inconvenience rather than a major health issue, but nevertheless it can disrupt athletic performance and it discourages an active lifestyle (Bø et al., 1989b; Nygaard et al., 1990), seriously reducing the quality of life for the affected individual (Coyne et al., 2008). In the elderly, it also predisposes to urinary tract and perineal infections, pressure ulcers and sleep disturbances. Moreover, the economic repercussions are considerable. In 1996, one study set the annual costs to the U.S. economy at $11.2 B for those living within the community and a further $5.2 B for those living in nursing homes (Fantl et al., 1996). In 2000, a second U.S. report estimated an annual cost of $19.5 B for a combination of urinary incontinence and a hyperactive bladder (Hiu et al., 2004). These may both be low estimates. The Canadian Continence Foundation estimated that in 2014 the direct annual costs to the Canadian economy were $2.3 B and indirect costs were $2.8 B, for a total of $6,263 per incontinent individual per year (Canadian Continence, 2014).

This review considers subjective and objective approaches to the appraisal of incontinence, and then examine the risk of urinary leakage in various classes of competitive athletes and in members of the general public who engage in vigorous physical activity. This review also examines how far the risk is modulated by regular physical activity and physical fitness, exploring the underlying patho-physiology, and concluding with a discussion of pelvic exercises and other specific treatments of this problem.

Methods

The Ovid/Medline database was searched from 1996 to July 2016. The MeSH term "Urinary incontinence" yielded 18,399 hits. Activity-related terms included "exercise" (113,883 hits), "physical exertion" (12,304 hits), "sports" (103,824 hits), "athletes" (5483 hits), or "physical fitness" (15,473 hits), for a total of 169,522 unique articles. Combining the 2 searches identified 243 specific articles. Review was limited to human studies that provided abstracts, without restriction of language. This identified 118 relevant papers linking incontinence with athletes (33), physical activity and fitness (16), risk factors, particularly obesity (15), methods of diagnosis (11), methods of treatment (38), and old age (5). The initial search was supplemented by a review of reference lists and the author's extensive personal files.

Results

Techniques for the appraisal of incontinence

Many investigators have relied on interviews, focus groups, questionnaires or postal surveys to assess whether a person suffered from urinary incontinence. It has not always been clear from the response to such techniques how frequent or serious the leakage was, and whether the issue was stress incontinence or some other form of urinary leakage. Moreover, because the body was already wet, incontinence may have been underreported by swimmers (Nygaard et al., 1994).

Other observers have assessed incontinence objectively, measuring urinary leakage as the increase in mass of a weighed sanitary pad (Eliasson et al., 2002; Fernandes et al., 2014; Hermieu et al., 2010; Karantanis et al., 2003; Persson et al., 2001; Stach-Lampinen et al., 2004), as a telemetrically-recorded decrease in the electrical resistance of the pad (Less, 2010), or as a low maximal pressure developed by the pelvic floor muscles, as assessed by a perineometer (Borin et al., 2013; Da Roza et al., 2013) or a vaginal pressure sensor (Morin et al., 2004; Morin et al., 2007; Peng et al., 2007).

The correlation between questionnaire responses and objective data obtained from weighed pads is only moderate (a kappa coefficient of 0.45 (Fernandes et al., 2014)). Hermieu and collaborators (2010) commented that in many women urinary leakage was indicated by an increase in mass of the sanitary pad, even though they had not admitted to any incontinence when completing a questionnaire (Hermieu et al., 2010). Eliasson and colleagues (2002) also found little relationship between objective measures of the extent of leakage and the maximal perineal pressure a woman could develop; nevertheless, their sample was small, and it may be that the relationship was obscured because all of the women that they tested were physically strong (Eliasson et al., 2002).

Magnetic resonance imaging has been used to identify individuals where stress causes an increased descent of the pelvic floor (Kruger et al., 2007), and another approach currently being explored is the recording of electromyograms from the pelvic floor muscles during a bout of physical activity (Luginbuehl et al., 2013).

Urinary incontinence in athletes and in physically active individuals

The literature research identified a total of 34 articles dealing specifically with urinary incontinence in athletes and military personnel with physically demanding assignments (Table 1). Issues to be considered are the prevalence and severity of urinary incontinence among participants in various sports relative to the general population of comparable age, together with the influence of the level of competition, and modifying risk factors such as parity and obesity.

Prevalence of urinary incontinence

The reported prevalence of incontinence depends in part on its definition. It ranges from the occasional leakage of a few drops of urine to a significant accumulation of fluid on protective pads. The frequency of occurrence varies from as rarely as once per year to most days of the week. The reporting of leakage may also be modified by the clothing that is worn during competition, with particular concern over avoiding visible soiling in such activities as gymnastics and figure-skating (Bø and Sundgot Borgen, 2001). Only six studies have made direct comparisons of the prevalence of stress incontinence between athletes and inactive individuals from the same population (Almeida et al., 2015; Bø and Sundgot Borgen, 2001; Caylet et al., 2006; Elleuch et al., 1998; Fernandes et al., 2014; Fozzatti et al., 2012), and even then the data have not always been controlled for important covariates. In a proportion of studies,

Table 1: Reports of urinary incontinence among athletes, former athletes and other active individuals.

Author	Sample	Survey type	Incidence	Comments
Abitteboul et al. (2015).	517 female amateur marathon or relay runners, mean age 41 yr	Cross-sectional questionnaire	30.7% had urinary incontinence, 16% during run	Usually seen towards end of the event, 7.5% at least 1/week
Alanee et al. (2009)	Amateur equestrians (31M, age 52.9 yr.; 173F, age 40.3 yr.) and control group [swimmers (79M, 102F)]	Mail and hand-distributed questionnaires	Multivariate analysis showed no increase of urinary symptoms in M or F with horseback- riding	No impact upon sexual dysfunction. Use of hard bicycle seat increased risk in F, trend to lower risk for equestrians than swimmers
Almeida et al. (2015)	67 committed female amateur athlete's age 18 yr. drawn from a large sports club vs. 96 non-athletes	Questionnaire on "any involuntary loss of urine"	Odds ratio of incontinence 2.9 for athletes vs. non-athletes	Risk in artistic gymnasts and trampoline 88.9%, swimmers (50%), judoku (75%)
Barreto et al. (2014)	47 active women, age 32 yr, parity 2.2 children, attending one of 2 gyms, half of group active > 1500 MET-min/week., average 546 MET-min/week.	Guided interview and ICIQ-SF questionnaire	72% reported urinary incontinence, 52% moderate incontinence on ICIQ-SF	Jumping 52.9%, squatting with weights 52.9%, leg press 29.4%, running 23.5%, walking 11.8%
Benjamin and Hearon (2000)	25 women aviators	Questionnaire	Exposure to high g force did not cause incontinence even in women with predisposition to incontinence	
Bø and Sundgot-Borden (2001)	660 elite female athletes, 766 controls, aged 15-39 yr.	Cross-sectional case-control postal survey	Similar prevalence in athletes and in controls (41%, 39%; social problem in 15%, 16%)	Parity less frequent in athletes than in controls. Incontinence in athletes linked to eating disorders.
Bø and Sundgot-Borden (2010)	331 former female athletes. 640 controls	Postal questionnaire, 81% response rate	When competing, 10.9% had stress, 2.7% urge incontinence; current prevalence 36.5% in athletes, 36.9% in controls	Incontinence while an athlete predicts subsequent incontinence [odds ratio 8.57 (3.55-20.77)]; athletes still more liable to leakage when active (20.4% vs. 15.3%)
Bø et al. (2011)	Fitness instructors (yoga & Pilates); 152 men, 685 women	On-line survey	Incontinence in 3/152 men; in F 21.4% >1/week, 3.2%, > 2/week, 1.7% > 1/day	"Bother" score 4.6
Borin et al. (2013)	40 women (10 volleyball, 10 handball, 10 basketball,10 controls) aged 18-30 yr.	Measurement of pelvic floor pressures with perineometer	Volleyball & basketball players developed significantly lower pressures; leakage correlated with low pressures (r = - 0.51)	Number of games/year & length of on-court work-outs negatively associated with maximal pressures
Bourcier (1990)	30 female athletes age 22 yr	Observation during feedback sessions	7% severe, 24% moderate, 33% mild urinary incontinence	Severe = continuous drip when exercising, moderate = with heavy lift or run, mild = with jumping

Table 1 continued.

Author	Sample	Survey type	Incidence	Comments
Carls (2007)	86 female athletes aged 14-21 yr	Cross-sectional survey of high school students, using Bristol questionnaire	>25% had slight incontinence, 2-4 times /week, to 2-4 times /month. 16% sufficient to have negative effect on social life, 8% avoided exercise	Low response (86/of 550 surveyed); 90% had never reported the problem or heard of Kegel exercises
Caylet et al. (2006)	157 elite female athletes, 426 controls aged 18-35 yr	Cross-sectional questionnaire	Stress incontinence in 28% of athletes, 9.8% of controls	Even a small loss of urine regarded as embarrassing
David (1993)	132 nulliparous female athletes, age 19.5 yr	Cross-sectional questionnaire	30% reported incontinence in daily life	
Da Roza et al. (2015a)	22 national-level female nulliparous trampolinists aged 18.1 yr	Cross-sectional questionnaire	Moderate urinary incontinence in 16/22 (72.7%) during practices, less than once/week in half of affected	Risk of incontinence related to training volume
Davis and Goodman (1996)	9 nulliparous female airborne trainees aged 21-31 yr, with stress incontinence	Self-administered questionnaire	6 weeks of rigorous airborne infantry training induced severe incontinence	Minimal incontinence before training
Davis et al. (1999)	563 female soldiers preparing for fitness testing	Self-administered questionnaire	31% commonly experienced incontinence during duty and/or training	Sufficient leak to interfere with job performance, & personal hygiene, socially embarrassing
de Araujo et al. (2008)	37 female distance runners, training 2.2-2.4 h/d, average age 35.4 yr	Gain in weight of absorbent pad over 1 hr.	23/37 (62%) complained of incontinence	Incontinence correlated with eating disorders
dos Santos et al. (2009)	58 respondents of 95 female physical education students aged 21.4 yr	Cross-sectional questionnaire	12/58 (20.7%) reported involuntary urine loss, mainly during sports activities (especially swimming & trampoline)	Seriousness of problem on 0-10 scale 2.3 (range 0-6); "frequent" in 22%
Eliasson et al. (2002)	35 female national level trampolinists, average age 15 yr	Cross-sectional postal survey, pad test on trampoline, measures of pelvic floor	80% reported incontinence on survey, 51.2% on pad test, 28.6% on pelvic floor strength, started after 2.5 yr of training	Leak averaged 28 g (9-56 g); no leak with laughs, coughs or sneezes
Eliasson et al. (2008)	305 female trampolinists, median age 21 yr, 85 competitive, 220 recreational level	Questionnaire	Prevalence of stress incontinence greater in competitive (76%) than in recreational trampolinists (48%)	Risk factors: frequency & volume of training, inability to interrupt urine flow and constipation
Elleuch et al. (1998)	105 female athletes, 105 non-athletes, aged 21.5 yr	Cross-sectional questionnaire	Stress incontinence in 62.8% of athletes (60% on daily basis), 34% of non-athletes	60% of athletes affected on daily basis. Risk factors childhood enuresis, constipation
Fatton et al. (2010)	330 respondents from 1065 female marathon runners, average age 45.9 yr	Cross-sectional questionnaire	39% had experienced urinary incontinence in previous month, one third wore protective pad	In 3/4, only a few drops of leakage.

Table 1 continued.

Author	Sample	Survey type	Incidence	Comments
Fernandes et al. (2014)	35 female adolescent amateur soccer players, age 15.6 yr, 24 controls	Pad test & questionnaire	Incontinence in 62.8% of athletes, vs. 25% in controls	Moderate reliability between pad test and questionnaire (kappa = 0.45)
Fischer and Berg (1999)	274 female U.S. aircrew, sometimes exposed to 9 g while flying	Anonymous questionnaire	Prevalence of incontinence 26.3%, much as in general population	Only 13 of 72 incidents occurred while flying
Fozzatti et al. (2012)	244 nulliparous women aged 20-45 yr, attending gyms vs. 244 controls (no obese subjects)	International incontinence questionnaire	Questionnaire scores 1.68 vs.1.02 in controls	Highest rates of incontinence during exercise in women jumping
Hermieu et al. (2010)	188 female runners	Pad test	Incontinence: 28.1% during 15 km walk, 51% for 10 km run, 60% for half-marathon, 75% for marathon	Many of women had not admitted to urinary incontinence on questionnaire
Jácome et al. (2011)	105 female athletes (athletics, basketball & football)	Questionnaire & focus group	Urinary incontinence in 41.5%, no difference between sports	Associated with lower body mass and BMI, avoided by preventive urination
Larsen and Yavorek (2007)	116 women, 37 involved in paratrooper training	Questionnaire & pelvic examination	24/116 had incontinence, unrelated to paratrooper training	Paratrooper training increased likelihood of pelvic prolapse
Mouly (2013)	264 recreational marathoners (aged 42.8 yr), 239 relay runners (aged 39.2 yr)	Cross-sectional questionnaire	31.4% of marathoners, 30.8% of relay runners incontinent	No different from general population
Nygaard et al. (1990)	290 female regular exercisers, average age 38.5 yr	Cross-sectional questionnaire	30% noted incontinence (running, 38%, high impact 36%, and tennis 27%)	17 stopped a particular exercise, 16 changed manner of exercising
Nygaard et al. (1994)	Female nulliparous university athletes (156, aged 19.9 yr)	Cross-sectional postal survey	28% experienced at least one episode of incontinence while practicing sport	Incontinence by sport: gymnastics 67%; tennis 50%; basketball 44%; field hockey 32%; track 26%; other sports <10%
Nygaard et al. (1996)	47 female varsity athletes in 5 sports, ages 18-20 yr	Blinded assessment of foot arch flexibility	Poor arch flexibility correlated with incontinence ($p = 0.03$)	
Nygaard (1997)	Former US female Olympic athletes (age 44 yr)	Retrospective postal survey	35.8% experienced incontinence; while competing: (swimmers 4.5%, gym/track 35%); now (swimmers 0%, gym/track 41%)	Significant differences while competing, $p < 0.005$
Poświata et al. (2014)	International or national level female runners aged 29.5 yr (55) and cross-country skiers aged 26.6 yr (57)	Anonymous questionnaire	45.5% leakage with sneezing or coughing	No difference between runners & skiers; 42.9% slightly bothered, 18.8% moderately bothered, 8% significantly bothered, 0.9% heavily bothered

Table 1 continued.

Author	Sample	Survey type	Incidence	Comments
Salvatore et al. (2009)	679 non-competitive Italian sportswomen, mean age 36 yr	Cross-sectional questionnaire	Urinary incontinence in 101 (14.9%), 32/101 during sport, 48/101 in daily life, 21/101 in both.	Highest for basketball, athletics, & tennis or squash. BMI and parity also risk factors
Schettino et al. (2014)	105 female volleyball players	Questionnaire	29.5% reported stress incontinence	65.7% had at least one symptom of stress incontinence
Simeone et al. (2010)	623 casual female athletes 18-56 yr, 12 sports	Anonymous questionnaire	30% had urinary incontinence, most frequent in soccer	Risk factors long training periods & practices, high impact
Thyssen et al. (2002)	8 national-level Danish sport clubs; 291 respondents of 396 women, aged 22.8 yr, 8.6% of group parous	Cross-sectional postal survey	Gymnastics, 56%. ballet 43%, aerobics 40%, badminton 31%, volleyball 30%, athletics 25%, handball 21%, basketball 17%	51.9% had incontinence in sport or daily life
Troël (2010)	66 females aged 22.7 yr, high-level participants in 10 sports (training 12.5 h/week)	Cross-sectional questionnaire	60.6% reported urinary incontinence, but only rarely in a half of these	Trampoline and running events most frequent cause, unlikely in low impact sports

ICIQ-SF = International consultation on incontinence questionnaire short form, METs = metabolic equivalents

generally of recreational rather than elite athletes, prevalence has been much as expected in the general population of similar age, but in about two thirds of reports the prevalence among some classes of athlete has been sufficiently high as to leave little doubt that the risk was increased relative to inactive individuals.

Reports showing no substantial impact of athletic involvement

Eight studies of athletes (mainly recreational rather than elite competitors) and three studies of military personnel in demanding employment) have shown an overall prevalence of incontinence similar to that expected in the general population, although often there has been comment that leakage occurred while engaged in competition.

Mouly (2013) studied 264 recreational marathoners aged ~ 42.8 yr and 39 relay runners (who covered only a quarter of the marathon distance) aged ~ 39.2 yr. More than 86% of this sample was only active at the recreational level, running an average of 29 km/week. Questionnaires indicated that 31.4% of marathoners and 30.8% relay runners were incontinent at least sometimes on the day of a race (although about a half of them said this only occurred "rarely"), typically towards the end of the event. Only 13% thought leakage was aggravated by their athletic activities. The risk was higher in those who with a history of a perineal birth (35.6% vs. 18.5%), and constipation was also a risk factor (Mouly, 2013). The findings were judged as similar to those for the general population of similar age. Abitteboul et al., (2015) collected further data on 517 female amateur-level marathon runners and relay runners. The average age of this group was ~ 41 yr, and the incidence of incontinence (30.7%) was again much as might be anticipated for the general population, although about a half of the sample noted that leakage occurred during the run (usually towards the end of the event, when they were feeling fatigued) (Abitteboul et al., 2015). The same individuals reported an 18.5% prevalence of incontinence during coughing or laughing, although they may have been more conscious of leakage under such circumstances than during a run (when they were sweating profusely). The only observed risk factors other than the immediate effect of running were age, parity and constipation. The frequency of occurrence was as often as once per week in 7.5% of the group, but in general the problem was considered as relatively minor, with embarrassment rated as no more than 1.6 on a 0-10 scale. Only 7% found it necessary to wear a protective pad during a race, only 2.9% reported an adverse effect on morale, and only 0.7% found it necessary to stop or modify their athletic activity.

Alanee and colleagues (2009) recruited 31 male and 173 female amateur equestrians, mainly from local riding clubs. The prevalence of incontinence was not stated, but a multivariate analysis showed no increase of risk with horseback-riding relative to the swimmers; indeed, in the women, there was a trend towards a lower risk for the equestrians than for the swimmers (Alanee et al., 2009).

Bø and Sundgot Borgen (2001) compared 660 elite female athletes aged 15-39 yr with 766 controls in a cross-sectional postal survey. The athletes participated in 38 different sports, but findings did not differ greatly between disciplines. At first inspection, the prevalence of stress or urge incontinence also seemed similar for athletes and controls (41% vs. 39%), with 15% and 16% finding it a social problem (Bø and Sundgot Borgen, 2001). However, an important issue in this study was the closeness of matching of controls, since parity (one important risk factor) was higher in the control group. It was also noted that both stress and urge incontinence were more prevalent in athletes with eating disorders, a fact previously reported by Hextall et al., (1999).

Dos Santos et al. (2009) obtained responses from 58 of 95 female physical education students aged an average of 21.4 yr; 12/58 (20.7%) of this group reported "frequent" involuntary urine loss, mainly during sports activities such as swimming and trampoline. However, the seriousness of the problem was rated as only 2.3 (range 0-6) on a 0-10 scale (dos Santos et al., 2009).

Nygaard et al. (1990) had 290 females who were regular exercisers (average age ~ 38.5 yr) complete a questionnaire. The prevalence of incontinence (30%) was much as expected for their age group, with somewhat higher rates for those involved in running (38%), high impact activities (36%) and tennis (27%). Nevertheless, leakage was sufficient for 17 of the 290 individuals to stop performing a particular type of exercise, and a further 16 changed their manner of exercising. Surprisingly, the incidence of leakage during weight-lifting was very low (7%) (Nygaard et al., 1990).

Salvatore and coworkers (2009) questioned 679 non-competitive Italian sportswomen with a mean age of ~ 36 yr. The overall prevalence of urinary incontinence was low (101/679 subjects, 14.9% of the total sample); 32 of the101 complained of leakage during sport (particularly during the high impact activities of basketball, athletics, tennis and squash), 48/101 had problems during daily life and 21/101 were affected in both situations. Despite the relatively low overall prevalence of incontinence, about a half of those who were affected complained of leakage at least 1-3 times per week, with 10% changing their sport and a further 20% modifying practice to reduce the risk of incontinence. Parity and a high body mass index were recognized as significant risk factors (Salvatore et al., 2009).

Simeone et al. (2010) collected data from 623 female athletes ranging in age from 18-56 yr. They participated in 12 different sports, overall, 30% of the group reported urinary incontinence, with the highest frequency among soccer players; however, this was not sufficient to be a barrier to participation. Risk factors were long training periods and practices, and high-impact activities.

Three reports looked at risks in military personnel with physically demanding employment. Benjamin and Hearon, (2000) questioned 25 women military aviators who were periodically exposed briefly to high g-forces; this did not cause leakage even in women who reported a predisposition to incontinence. Fischer and Berg, (1999) questioned a larger sample of 274 female U.S. aircrew who were sometimes exposed to forces as high as 9 g while they were flying. Responses to an anonymous questionnaire set the overall prevalence of incontinence at 26.3%, much as in the general population. Only 13 of 72 incidents occurred while flying, and leakage was more likely when off-duty (particularly when exercising). Other risk factors included age, vaginal parity and crew position (with the highest rates being seen among the weapon-systems operators). Reasons for the variation in risk with crew position remain obscure. Larsen and Yavorek, (2007) studied a further 116 women aged ~19.6 yr who were attending the U.S. Military Academy; 37 of this group were involved in paratrooper training. The authors made a pelvic examination after subjects had completed a questionnaire. Twenty-four of the sample reported incontinence. This was unrelated to their paratrooper training, but was associated with running. Ninety-two percent of the group exercised for 60 minutes at least 3 times per week, with running forming a major part of the workout for 77% of the group.

Reports of increased risk in athletes

One possible factor influencing the vulnerability to urinary incontinence in athletics is the flexibility of the arch of the foot, and thus the extent of shock absorption when making a hard landing (Nygaard et al., 1996a). A trial of arch flexibility in 47 female varsity athletes aged from 18 to 20 yr, and drawn from five different sports, found a significant association between flexibility and urinary incontinence.

Twenty studies of athletes, mostly at the elite level, and 2 studies of military personnel have reported a higher rate of urinary incontinence than expected in the general population. Almeida and colleagues compared 67 female amateur but very committed athletes (mean age ~ 18 yr) from a large sports club with 96 non-athletic controls drawn from a teenager health centre and a class of physiotherapy/physical education students. The athletes were practicing sport an average of 19 hours per week. The odds ratio of incontinence was substantially increased for the athletes (2.9 (95% CI 1.50-6.51)), with respective prevalence's of 52% and 27% for the 2 subject groups. The most vulnerable individuals were gymnasts and trampolinists (88.9% affected), but prevalence was also high in swimmers (50%) and judo contestants (44%), compared with 27.1% in the non-athletes (Almeida et al., 2015).

Barreto et al., (2014) examined 47 women aged 32 yr who were attending one of 2 gymnasia. Their average involvement in physical activity and sport was estimated at a substantial 546 MET-min/wk., and more than a half of the sample had an energy expenditure of over 1500 MET-min/wk. Some 72% reported some urinary incontinence, and 52% showed a moderate degree of incontinence (a score of 10.5 on the International consultation on incontinence questionnaire short form). When exercising on their own, incontinence was provoked by an increase in the intensity of exercise (29%), running (29%), crouching (18%), skipping (18%) and lifting weights (6%); gymnasium activities that provoked incontinence included jumping (53%), squatting with weights (53%), leg presses (29%), running (24%), and walking (12%). About a half of the group with incontinence deliberately avoided these activities.

Borin et al. (2013) used a perineometer to measure pelvic floor pressures in a small sample of 40 women aged 18-30 yr (10 volleyball, 10 handball, and10 basketball players, plus10 controls). Urinary leakage was significantly correlated with low perineal pressures ($r = -0.51$), and the maximum pressures developed by the volleyball and basketball players were significantly lower than those seen in the controls. The number of games played per year, strength-training times, and the length of on-court work-outs were all negatively associated with perineal pressures.

Bourcier (1990) reported data for 30 female athletes aged 22 yr. Observations were made during feedback sessions, with findings of more urinary incontinence than would be anticipated in young non-athletes. Leakage was rated as severe in 7% (with a continuous drip when exercising), and in a further 24% it was moderate (related mainly to heavy lifting or a run). For the final 33%, the problem was mild (being encountered only when jumping).

Carls (2007) distributed the Bristol questionnaire on urinary incontinence to the coaches of 550 high school athletes, although 86 students only returned the form from unspecified athletic disciplines. Given the young age of these competitors, the prevalence of incontinence appeared to be greater than for non-athletes, although the data must be interpreted very cautiously, given the low response rate. More than 25% of respondents reported slight incontinence, ranging from 2-4 times/week to 2-4 times/month; in 16%, the leakage was sufficient to have a negative effect on their social life, and 8% avoided exercise because of this problem. However, 90% of the group had not previously reported their incontinence, and most of the group were unaware of the value of Kegel-type exercises. Caylet and colleagues (2006) carried out a case-control survey of 157 elite female athletes aged 18-35 yr, and 426 controls. Stress incontinence was reported by 28% of the athletes, but by only 9.8% of the controls. In both groups, the leakage was often minor, but was nevertheless regarded as embarrassing, and commonly was not spoken about. Among the athletes, leakage tended to occur in the second half of training or a competitive event, as they became tired, but among the controls leakage occurred both when they were physically active and when they were inactive (Caylet et al., 2006).

David (1993) questioned 132 nulliparous female athletes, aged 19.5 yr; 30% reported some degree of incontinence during daily life. Although there were no controls in this study, the prevalence of leakage seems greater than would have been expected in this age group.

Da Roza et al. (2015a) examined data for 22 national-level female nulliparous trampolinists with an average age of 18.1 yr. Urinary incontinence (typically rated as moderate) was reported by 16/22 (72.7%) women during practices. The risk increased with training volume and with years of training. It is unclear if the latter reflects a progressive participation in more demanding manoeuvres or a cumulative effect of involvement in the sport; however, none of the group had noted incontinence before they began trampoline training. The frequency of leakage was less than once a week in a half of those affected, and two thirds stated that there was little effect on their daily lives. A comparison of seven continent athletes with five who were incontinent led to the somewhat surprising discovery that the pubo-visceral muscles were thicker in the second group (Da Roza et al., 2015a); again, this could possibly reflect progressive involvement in a physically more demanding programme.

de Araujo and colleagues (2008) assessed incontinence objectively, from the gains in weight of an absorbent pad over a one-hour collection period. Their subjects were a group of 37 female distance runners of average age 35.4 yr who were training 2.2-2.4 hours per day; 23/37 (62%) of this group complained of incontinence, and an interesting feature of this study was a linkage between such leakage and the presence of eating disorders (de Araujo et al., 2008).

Eliasson et al. (2002) evaluated incontinence in 35 adolescent female national level trampolinists, with an average age of 15 yr. Data were collected using a postal survey, a pad test while they were active on the trampoline, and perineometer measurements of pelvic floor strength. Some 80% reported incontinence, 51.2% demonstrated leakage on the pad test, and 28.6% showed limitations of pelvic floor strength. Those affected were older, and had trained for a longer period. The volume of leakage averaged 28 g (range 9-56 g), and it usually occurred towards the end of a training session or after a double-somersault. No leakage was seen with laughs, coughs or sneezes; however, 28 of the 35 used protective pads during their sport (Eliasson et al., 2002). As in the study of Da Roza and colleagues (2015a), problems were not present on recruitment to the trampoline programme, but had started an average of 2.5 yr after they had begun training; weakness of the pelvic floor suggested that some members of the group had sustained an injury during jumping. Eliasson et al. (2008) expanded their sample to include 85 elite and 220 recreational trampolinists aged ~ 21 yr. As expected, the prevalence of stress incontinence was substantially greater in competitive (76%) than in recreational trampolinists (48%). Incontinence most commonly occurred when trampolining, but in 71 of the 305 it also happened at other times. The frequency of leakage was commonly rated as occasional (72%), but in 20% it had occurred "several times," and in 6% "often." Risk factors included the frequency and volume of training, an inability to interrupt urine flow and constipation.

Elleuch and associates (1998) compared 105 female athletes (respondents from a sample of 150, aged 21.5 yr) with 105 non-athletes. Typically, the athletes were training 5 or more hr per week. The respective prevalence's of stress incontinence were 62.8% (60% on a daily basis) and 34%, with the only significant risk factors other than sport being bed-wetting as a child and constipation. Only 18 of the athletes had reported the problem to a third party, and only 1 had consulted a health professional (Elleuch et al., 1998). The problem was most frequent in sports that involved impact, with figures of 25% for athletics, 18% for basketball, 17% for handball and 15% for volleyball, but only 3% for swimming (Ghroubi et al., 2015).

Fatton and colleagues (2010) questioned 330 of 1065 female marathon runners, with an average age of 45.9 yr; 39% of the respondents had experienced urinary incontinence in the previous month, and one third wore a protective pad when exercising. However, in about three quarters of the group, the extent of leakage was reported as no more than a few drops (Fatton et al., 2010).

Fernandes et al. (2014) compared 35 female adolescent amateur soccer players; age 15.6 yr, with 24 controls, using both a questionnaire and a pad test. Incontinence was seen in 62.8% of the athletes, but in only 25% of the controls (Fernandes et al., 2014).

Fozzatti and associates (2012) evaluated 244 nulliparous women aged 20-45 yr who were attending gyms and 244 controls. After eliminating obese individuals from the comparison, respective scores on the International incontinence questionnaire were 1.68 and 1.02. The highest rates of incontinence during exercise were seen with activities that involved impact- jumping (25.0%), stepping (23.3%) and running (19.5%) (Fozzatti et al., 2012).

Hermieu and colleagues (2010) applied a pad test to 188 female runners. Incontinence increased with both running intensity and distance, being only 28.1% during a 15-km walk, but 51% for a 10-km run, 60% for a half-marathon, and 75% for a full marathon run. Many of those affected had not admitted to urinary incontinence on a standard questionnaire (Hermieu et al., 2010).

Jácome et al. (2011) recruited 105 female athletes who were involved in athletics, basketball or soccer; practice times ranged from 4-8 hours per week. The prevalence of urinary incontinence was 41.5%, as ascertained by questionnaires and focus groups. No difference of prevalence was found between these sports, all of which involve some impact. However, risk was significantly increased in athletes with a lower body mass ($p = 0.01$) and body mass index ($p = 0.035$); basketball and soccer are not usually associated with eating disorders, and the explanation of this anomaly remains unclear. The volume of leakage was generally small (no more than a few drops) and occurred rarely. Few of the group had discussed their problem with a health professional.

Nygaard et al. (1994) conducted a cross-sectional postal survey of 156 nulliparous female varsity athletes of average age 19.9 yr, finding that 28% had experienced at least one episode of incontinence while practicing their chosen sport. Dividing data by athletic discipline, the respective rates (gymnastics 67%, tennis 50%, basketball 44%, field hockey 32%, track 26%, and other sports <10%) showed the typical predominance among high-impact activities. The frequency of leakage showed parallel differences with sport, 20% of gymnasts reporting frequent leakage. Activities most likely to provoke leakage were noted as jumping with the legs apart (30%) or together (28%), running (30%) and making impact with the floor (14%). Some 42% of the group also had episodes of incontinence during daily life (coughing, sneezing, heavy lifting or hearing running water), at a frequency matching that seen during practice of their given sport. Some 38% of those affected reported embarrassment from their problem (Nygaard et al., 1994).

Poświata et al. (2014) found a high incidence of urinary incontinence in a sample of 55 international or national level female runners aged ~ 29.5 yr and 57 cross-country skiers aged ~ 26.6 yr. Reports on an anonymous questionnaire showed 45.5% of their sample reporting some leakage during physical activity, sneezing, or coughing, but no significant difference between runners and cross-country skiers. In terms of the severity of the problem, 42.9% were said to be "slightly bothered," 18.8% "moderately bothered," 8% "significantly bothered," and 0.9% "heavily bothered" (Poświata et al., 2014).

Schettino and coworkers (2014) studied 105 female volleyball players. At 29.5%, the prevalence of actual stress incontinence was only moderately greater than in inactive individuals, but 65.7% of the athletes reported one or more symptoms of stress incontinence and/or urgency in sport and/or daily life (Schettino et al., 2014).

Thyssen et al. (2002) conducted a cross-sectional postal survey on 396 women aged 22.8 yr who were active in 8 national-level sports clubs. There were 291 respondents, and 8.6% of the group was parous. Overall, 51.9% reported some incontinence in their sport or daily life. Leakage was a frequent occurrence in only 4% of the sample, but 60% of those reporting leakage elected to wear protective pads at least occasionally. Jumping was cited as the most frequent precipitating factor; respective values for individual sports were gymnastics 56%, ballet 43%, aerobics 40%, badminton 31%, volleyball 30%, athletics 25%, handball 21%, and basketball 17%. In this study, as in several others, leakage was more frequent during training than in competition, and the authors suggested that higher catecholamine's may have helped to keep the urethra closed during competition (Thyssen et al., 2002).

Troël (2010) reported findings on 66 high-level female performers aged 22.7 yr. They were participating in one of 10 sports, and 60.6% of the group reported urinary incontinence (although only "rarely" in a half of those with complaints). Trampoline and running events were the most frequent causes of leakage, and problems were unlikely in low-impact sports (Troël, 2010).

One further report on military personnel is of interest in suggesting that physical damage can occasionally occur during jumping. Davis and Goodman, (1996) examined nine nulliparous female airborne trainees aged 21-31 yr who were complaining of stress incontinence. These women were selected from a group of 420 trainees because they had minimal incontinence when first recruited. After 6 weeks of rigorous airborne infantry training, they had developed severe incontinence (a loss of 13-64 g of urine in 1 hr following a training exercise that included sit-ups, push-ups and a 2-mile run). Four of the nine had reported a tearing pain in the right lower quadrant during a parachute jump (Davis and Goodman, 1996). A further study by Davis' group involving 563 female soldiers who were preparing for fitness testing found that 31% of respondents commonly experienced incontinence during duty and/or training, and that this was sufficient to interfere with job performance and personal hygiene, as well as being socially embarrassing (Davis et al., 1999).

Type of exercise. A number of reports have shown that the prevalence of urinary incontinence is high amongst those who engage in high-impact activities (trampolinists, gymnasts, soccer, basketball, handball and hockey players, ballet dancers and runners)(Almeida et al., 2015;Barreto et al., 2014;Eliasson et al., 2008;Nygaard et al., 1994;Thyssen, et al., 2002;Troël, 2010), where athletes are subjected to sudden and repeated increases of intra-abdominal pressure (Caylet et al., 2006) and ground reaction forces as much as 4 times body mass (Groothausen, Siemer, Kemper, and Welten, 1997). In contrast, the prevalence of leakage is usually very low during the practice of sports such as golf and swimming, where there is little physical impact (Nygaard et al., 1994), although for some unexplained reason one report found a 50% prevalence of incontinence in swimmers (Almeida et al., 2015).

Interestingly, problems seem more prevalent during training than during competition, possibly because the catecholamine that is secreted during competition acts on urethral a-adrenergic receptors, facilitating closure of the urethral sphincter (Da Roza et al., 2015a; Thyssen et al., 2002).

Level of competition. It is apparent from comparisons between high-level and recreational athletes that the prevalence of stress incontinence is high among elite competitors, and is much lower in non-competitive athletes (Eliasson et al.; Hermieu et al., 2010; Salvatore et al., 2009). No effects were seen from horseback riding at an equestrian club (Alanee et al., 2009), among walkers (Barreto et al., 2014), or in aviators with occasional exposure to high g forces (Benjamin and Hearon, 2000; Fischer and Berg, 1999).

It is less clear whether the prevalence among top competitors is due to the greater length of training sessions, with resulting fatigue of the pelvic floor muscles, the greater impacts sustained in many athletic manoeuvres, or semi-permanent damage to the pelvic floor. Certainly, some initially continent competitors find that leakage develops over several years, as they progress in their sport (Da Roza et al., 2015a; Eliasson et al., 2002).

Severity of leakage. In many recreational athletes, the leakage is small, occurs infrequently, and is readily countered by use of a perineal pad. Thus, a number of authors stated that leakage occurred "rarely" (Eliasson et al., 2008; Mouly, 2013; Troël, 2010), usually amounted to only a few drops (Fatton et al., 2010; Jácome et al., 201) , or was not generally a significant problem (Abitteboul et al., 2015; Caylet et al., 2006). Abitteboul and colleagues rated the average level of embarrassment as no more than 1.6 on a 0-10 scale, and dos Santos et al. (2009) found that physical education students scored the seriousness of even "frequent" involuntary urine loss as only 2.3 (range 0-6) on a 0-10 scale (Abitteboul et al., 2015). In a survey of 82 incontinent women with active leisure pursuits, Stach-Lampinen and associates (2004) reported an average urinary loss of 26 g over 24 hours. However, the habitual physical activity of this group remained as great as that of the general population, and their exercise habits were not increased by the subsequent successful treatment of their problem (Stach-Lampinen et al., 2004).

However, in up to 10% of athletes with complaints, the volume of urinary leakage is significant and the frequency of occurrence is greater. One study found an average leakage of 28 g of urine during 15 minutes of activity on the trampoline (Eliasson et al., 2002). Barreto and colleagues reported that 52% of women who were attending 2 gymnasia showed a "moderate" degree of incontinence (a score of 10.5 on the International consultation on incontinence questionnaire short form) (Barreto et al., 2014), and for Salvatore and team about a half of those with incontinence complained of leakage at least 1-3 times per week (Salvatore et al., 2009). Bourcier (1990) rated leakage as severe in 7% of those who were incontinent (with a continuous drip when exercising), and in a further 24% of subjects it was "moderate" (related mainly to heavy lifting or a run). Elleuch and associates found that 60% were affected on a daily basis, and the problem was "frequent" for the gymnasts studied by Nygaard and colleagues (Elleuch et al., 1998; Nygaard et al., 1994).

In some samples, social problems have been correspondingly minor, with embarrassment rated as no more than 1.6 on a 0-10 scale (Abitteboul et al., 2015); although 7% of their runners chose to wear a protective pad during a race, only 2.9% reported an adverse effect on morale, and 0.7% found it necessary to stop or modify their athletic activity. Da Roza et al. (2015a) commented that in two thirds, the incontinence had little effect on their daily lives. Poświata and colleagues categorized the severity of the problem, finding that 42.9% were "slightly bothered," 18.8% "moderately bothered," 8% "significantly bothered," and 0.9% "heavily bothered" (Poświata et al., 2014). But the level of embarrassment seems to vary with the culture, and in the sample of Bø and Sundgot Borgen (2001) 15% of 660 elite female athletes and 16 % of 766 controls found incontinence was a social problem. Likewise, Carls (2007) noted that in 16% of high school athletes, leakage was sufficient to have a negative effect on their social life, and 8% avoided exercise because of this problem.

The problem may be sufficient to affect performance adversely, and even to persuade the competitor to modify performance or to abandon a particular sport (Brown and Miller, 2001; Norton, 1982; Nygaard et al., 1990; Nygaard et al., 2005). Over 10% of non-competitive Italian sportswomen with urinary incontinence chose to abandon their sport, and a further 20% altered their manner of play (Salvatore et al., 2009). Nygaard and associates (1990) also reported that leakage in 17 of 290 regular exercisers was sufficient to stop participation in a particular type of exercise, and a further 16 of athletes opted to change their manner of exercising. Likewise, Barreto et al. (2014) found about a half of their group of gymnasts with incontinence deliberately began to avoid specific types of physical activity (Nygaard et al., 1990).

Long-term effects of athletic participation. We have noted already some hints of long-term effects from high-impact sports- the progressive development of incontinence over several years of sport involvement, the loewr pelvic pressures developed by those athletes with incontinence, and the suggestion of specific injury during parachute jumping. Eliasson and colleagues (2008) found that incontinence remained more frequent in ex-trampolinists than in controls 5-10 yr after ceasing the sport (p = 0.001); 12 of 16 athletes who had stopped trampolining because of urinary leakage found that the problem persisted. However, current high impact physical activity did not appear to enhance the risk of continuing leakage, and regular low impact activity tended to promote continence relative to those who were taking no physical activity (Eliasson et al., 2008).

However, Bø and Sundgot-Borgen (2010) saw little evidence of long-term effects from high-impact sports in a retrospective questioning of 331 former female participants (now aged 37.5 yr, and drawn from 38 athletic disciplines) and 640 controls. A postal questionnaire yielded a response rate of 81%. When they were competing, 10.9% of the athletes had complained of stress, and 2.7% of urge incontinence; the current prevalence of incontinence was 36.5% in athletes, and 36.9% in the controls. Although there was now no inter-group difference in leakage during coughing or sneezing, nevertheless incontinence was more common in the former athletes when they undertook physical activity (20.4 vs. 15.3%), and a history of former incontinence was a strong predictor of current leakage (odds ratio 8.57 (3.55-20.77)). Findings in this study did not differ between those formerly involved in low, medium or high impact sports. A small-scale comparison was also drawn between the course of pregnancy in 40 Norwegian athletes and 80 controls. No differences were found with respect to low back pain, girdle pain and pelvic floor pain during pregnancy and following childbirth (Bø and Backe-Hansen, 2007).

Nygaard (1997) also made a retrospective postal survey of former U.S. Olympic athletes when they had attained an average age of 44 yr, 20-30 yr after competing. Some 35.8% had experienced incontinence while they were involved in their sport, with a large difference between swimmers 4.5%, and gym/track competitors 35%). Currently, the swimmers had 0% complaints, and gym and track athletes 41%, with parity and a high body mass index as risk factors. There was no current difference in the risk of incontinence between those who had been involved in high or in low impact sports. It thus appears that although there may be effects that persist for 5-10 yr, healing may eventually occur.

Associations between habitual physical activity, fitness and incontinence

Possible associations between habitual physical activity, fitness and incontinence need to be considered in relation to the age of the population. In young adults, a vigorous daily work-out may include high-impact activities that are liable to precipitate urinary incontinence, but in an older population the maintenance of muscle tone and a good level of physical fitness seems likely to enhance the strength of the pelvic floor muscles and reduce the risk of urinary leakage (Eliasson, Nordlander, Larson, Hammarström, and Mattson, 2005). Moreover, regular physical activity could serve to control body mass index and regulate other facets of lifestyle such as smoking that are associated with incontinence.

There have as yet been no randomized controlled trials examining relationships between habitual physical activity and urinary incontinence. Most studies have adopted a cross-sectional design, leaving it unclear whether urinary incontinence has limited the individual's physical activity or whether sedentary behaviour has increased the risk of incontinence (Table 2).

Table 2: **Influence of habitual physical activity upon the risk of urinary incontinence.**

Author	Sample	Survey type	Findings	Comments
Barretto et al. (2014)	47 women aged 32 yr, exercising regularly (49% > 1500 MET-min/week.)	Guided interview	72% reported urinary incontinence, 52% showed moderate incontinence on ICIQ-SF	Jumping 52.9%, squatting with weight 52.9%, leg press 29.4%, running 23.5%, walking 11.8%
Bø et al. (1989)	Physical education students vs. nutrition students	Questionnaire	Urinary leakage in 26% of physical education and 19% of nutrition students	Most active physical education students versus the most inactive nutrition students (31% vs. 10%)
Bradley et al. (2005)	297 women aged 68 yr	Questionnaire	Urinary urgency less prevalent in women exercising at least 1/week (23.8% vs. 35.2%)	High body mass index a risk factor
Brown and Miller (2001)	1051 of 1500 female Australian participants in fitness survey, age 21-79 yr who previously reported incontinence	Questionnaire	Leakage in past month: young (20-26 yr, 77%), middle-age (48-53 yr, 95%), elderly (73-79 yr, 95%)	Incontinent avoided sporting activities: young (7%), middle-aged (a third), elderly (a quarter)
Brown et al. (2006)	1957 women with diabetes, aged ~50 yr, lifestyle programme vs. metaformin vs. control group	Questionnaire, 150 min moderate activity/week for lifestyle group	After 2.9 yr, lower risk of incontinence with lifestyle (31.3%) than metaformin (39.7%) or control (36.7%)	Effect of lifestyle intervention mainly due to reduction of body mass
Burgio et al. (1991)	541 women aged 42-50 yr	Questionnaire	58.7% showed some incontinence, 30.7% regular leakage	Continence related to BMI and ethnicity, but not to habitual physical activity
Burti et al. (2014)	56 women, age 52 yr (30 incontinent)	Electromyogram	Maximal pelvic floor muscle contractions to fatigue, 9.1 min in incontinent, 14.2 min in continent	
Danforth et al. (2007); Devore et al. (2013)	Nurses' health study, initial age 54-79 yr, 2355 cases of incident incontinence	Biennial reporting of physical activity, self-reports of incident leakage of urine (2355 cases)	Odds ratio of leaking urine 0.81 (0.71-0.93) (highest vs. lowest physical activity quintile, 28.6 vs. 6.2 MET-h/week)	Greater benefit for stress than for urge incontinence; most of activity undertaken was moderate, e.g. walking
Eliasson et al. (2004, 2005)	665 women before & after birth of first child	Questionnaire at 36th week of pregnancy and at 1 year post-partum	High impact exercise before pregnancy risk factor for urinary leakage, but low impact exercise protective	Urinary leakage before pregnancy usually persisted 1 year post-partum
Hannestad et al. (2003)	27,936 Norwegian women aged > 20 yr	Questionnaire	Low impact physical activity reduces risk, but not high impact activity	Strong association of leakage with BMI, weak association with smoking

Table 2 continued.

Author	Sample	Survey type	Findings	Comments
Kikuchi et al. (2007)	Men and women aged > 70 yr (507 not incontinent, 169 incontinent)	Questionnaire	Odds ratio of incontinence relative to inactive 0.71 (middle), 0.58 (high) physical activity tertile	Prevalence of incontinence 34% in women, 16% in men
Kim et al. (2011)	61 elderly Japanese women, aged ~ 79 yr, 31 intervention, 30 control	3-month multi-dimensional exercise programme 2/week	Incontinence in intervention drops from 66.7 to 22.3%, no change in controls	Follow up incontinence 40%
Lee and Hirayama (2012)	700 M, 300 F aged 66 yr	Questionnaires & interview	Incontinence in 7.2% M, 27.5% F; multivariate risk if walking >1000 MET-min/week M = 0.36 (0.14-0.92), F = 0.43 (0.20-0.96)	Benefits not statistically significant for moderate activity or total activity
Moreno-Vicino et al. (2015)	471 non-institutionalized women aged >65 yr	Questionnaire & fitness testing	Incontinence in 28.5%. Risk linked to BMI and low fitness index, particularly upper body flexibility	Incontinence also more likely if low daily volume of walking
Morrisoe et al. (2014)	328 Latinos aged 60-93 yr enrolled in 1 year walking programme	Questionnaire, pedometer & fitness tests	Incontinence 17.4% at 1 year; related to low initial step count, gains on physical performance score (OR 0.69 [0.50-=0.95])	Continence also related to health-related quality of life.
Nygaard et al. (2005)	3364 women aged 18-60 yr	Questionnaire on interference with exercise	Multivariate analysis; women with severe leakage less likely to take adequate physical activity (2.64 [1.25-5.55])	
Nygaard et al. (2015)	Case/control moderate or severe incontinence vs. mild or none, 1538 women aged 39-65 yr	Incontinence severity index scores relative to physical activity questionnaire	Incontinence increased slightly with lifetime physical activity (odds ratio 1.20 [1.02-1.41]), but not with lifetime strenuous activity	Strenuous activity as a teen increased incontinence
Smith et al. (2010)	441F, 131M Latino aged 60->85 yr recruited to walking programme	Yale physical activity index	Energy expenditure = 0.82 (0.35-1.90) Activity dimensions score = 0.77 (0.60-0.98)	Body mass index not a risk factor
Stach-Lempinen et al. (2004)	82 incontinent women, 69 seen again 1 year after successful treatment	Urinary pad, estimated energy expenditure in work, sport & leisure, Caltrac accelerometer	No change in any measure of activity one year after successful treatment	
Sung et al. (2012)	85 candidates for sling operation	Activity questionnaire	Pre-operative activity level averaged 396 MET-min/week	
Townsend et al. (2008)	116,671 female nurses, 4081 incident cases of urinary incontinence	Questionnaire, prospective study	Stress and urge incontinence relative risk 0.75 top vs. bottom physical activity quintile	Relative risk attenuated by adjustment for BMI- benefit partly due to weight maintenance?
Yoshida et al. (2007)	785 M, 1015 F aged > 70 yr	Questionnaire, walking speed, physical activity	Incontinence 13.4% M, 23.3% F. Risk factors: M lack of fitness, poor nutrition; F lack of fitness, obesity, lack of activity, poor mental health	
Zhu et al. (2008)	5300 women, aged >20 yr.	Questionnaire	Incontinence 38%; multiple logistic analysis shows risk from lack of exercise [1.3 (1.1-1.50)]	Other risks: age, multiple vaginal births, menopause, obesity, constipation, hypertension

Habitual physical activity and incontinence

Young and middle-aged adults. Nine articles have examined interactions between habitual physical activity and incontinence in young and middle-aged adults. Six of these reports (Barreto et al., 2014; Bø, Maehlum, et al., 1989; Brown and Miller, 2001; Eliasson et al., 2005; Hannestad et al., 2003; Nygaard et al., 2015) found that vigoroushabitual activity increased the likelihood of incontinence, but three of the six articles (Brown and Miller, 2001; Eliasson et al., 2005; Hannestad et al., 2003) and one other report (Zhu et al., 2008) also found that regular moderate activity reduced the risk.

Barreto and colleagues (2014) carried out a guided interview on 47 women of average age 32 yr, Combining data for attendance at a sports club, active commuting and housework yielded a high estimated weekly energy expenditure for their subjects (in 49%, more than 1500 MET-min/wk); 72% of the group reported urinary incontinence, and 52% showed what was classed as "moderate" incontinence on the ICIQ-SF standardized questionnaire. Many of the group was engaged in athletic activities, and incontinence was linked to jumping (52.9%), squatting with weights (52.9%), leg presses (29.4%), running (23.5%), and walking (11.8%) (Barreto et al., 2014). Bø et al. (1989) compared physical education and nutrition students, finding a slightly higher incidence of incontinence in the physical education students (26% versus 19%). This difference seemed related to a greater level of habitual physical activity in the physical education students, since 31% of the most active members of this group, but only 10% of the most inactive nutrition students reported incontinence.

Brown and Miller (2001) questioned 1051 of 1500 females' age 21-79 yr who had previously reported exercise-induced incontinence in an Australian fitness survey. Almost all of these women still reported leakage over the previous month, figures being for the young (20-26 yr) 77%, for the middle-aged (48-53 yr) 95%, and for the elderly (73-79 yr) 95%; 7% of the young. a third of the middle-aged and a quarter of the elderly had in consequence deliberately avoided participation in athletic activities.

Eliasson and colleagues (2005) studied 665 women who were initially aged 28 yr before and after the birth of their first child. A questionnaire was administered at the 36th week of pregnancy (when 39% reported urinary leakage) and 1 year post-partum. High impact exercise before pregnancy was a risk factor for urinary leakage, but low impact exercise tended to be protective (respective rates: high impact 44%, low impact 30%, no physical activity 35%). Moreover, if there had been urinary leakage before pregnancy, this usually persisted for at least a year post-partum, and about a quarter of those who were initially free of leakage developed this post-partum (Eliasson et al., 2005). Eliasson and associates (2008) further noted that current high impact physical activity did not appear to enhance the risk of continuing leakage, and regular low impact activity tended to promote continence relative to those who were taking no physical activity (Eliasson et al., 2008).

Hannestad and coworkers (2003) questioned 27,936 Norwegian women over the age of 20 yr. Incontinence increased with age, from 18% (20-44 yr) to 28% (45-69 yr) and 33% (over 70 yr). In a multivariate analysis, the volume of low-level physical activity was shown to have a weak negative association with stress incontinence (odds ratios for >3 h/week versus < 1 hr/week of physical activity 0.8 (0.7-0.9) for all incontinence, 0.6 (0.4-0.8) for severe incontinence and 0.4 (0.3-0.7) for severe urge incontinence). In contrast, values for high impact activity (also >3 hr/wk. versus < 1 h/week) showed a non-significant trend to an increase of risk for the more active individuals. Incontinence was strongly related to body mass index, and also showed a weak association with smoking (Hannestad et al., 2003).

In a case-control study, Nygaard et al. (2015) examined whether moderate or severe incontinence was related to habitual physical activity in a sample of 1538 women aged 39-65 yr. Incontinence increased slightly with a history of lifetime physical activity (an odds ratio of 1.20 (1.02-1.41) for each additional 70 MET-hr of energy expenditure per week), but it was not associated with the lifetime volume of strenuous activity; strenuous activity as a teenager seemed to be the main culprit.

Nygaard and colleagues (2005) examined how far incontinence interfered with exercise in a sample of 3364 women ranging widely in age from 18-60 yr. A multivariate analysis confirmed that women with severe leakage were more likely to take an inadequate amount of habitual physical activity (odds ratio 2.64 (1.25-5.55)) (Nygaard et al., 2005). Incontinence was perceived as a moderate or substantial barrier to exercise in 9.8% of the sample (Nygaard et al.,1990; Nygaard et al., 2005).

Stach-Lampinen and associates (2004) observed an average urinary loss of 26 g over 24 hours in 82 women with active leisure pursuits. However, the physical activity of those who were incontinent was just as great as that of the general population, and their exercise habits (work, sport and leisure) as assessed by questionnaires and use of a Caltrac accelerometer were unchanged by successful treatment of their problem (Stach-Lampinen et al., 2004).

Zhu and colleagues (2008) questioned 5300 women over the age of 20 yr; 38% of this sample complained of incontinence, and a multiple logistic analysis showed lack of exercise was a significant risk factor (odds ratio 1.3 (1.1-1.5). Other risk factors were age, multiple vaginal births, menopause, obesity, constipation, and hypertension (Zhu et al., 2008).

Elderly individuals. There have been eight reports on six studies of incontinence and habitual physical activity in elderly individuals. In five studies, urinary urgency and/or incontinence was linked to a low level of physical activity (Bradley, Kennedy, and Nygaard, 2005; Danforth et al., 2007; Devore et al., 2013; Kikuchi et al., 2007; Lee and Hirayama, 2012; Sung et al., 2012; Townsend et al., 2008), but Burgio et al. (1991) found no such relationship.

Bradley et al. (2005) studied 297 elderly women with an average age of 68 yr. They found that urinary urgency was less prevalent in those exercising at least once per week (23.8% vs. 35.2% in the more inactive members of the group, multivariate odds ratio 0.6 (0.4-1.0)). There was also a tendency to an increased risk of incontinence with a high body mass index (odds ratio 1.8 (0.8-4.0)).

Burgio and colleagues (1991) questioned 541 women aged 42-50 yr. Some incontinence was reported by 58.7%, and 30.7% complained of leakage at least once per month. In this sample, continence was related to body mass index and ethnicity, but not to habitual physical activity, parity, smoking or other variables (Burgio et al., 1991).

Danforth et al. (2007) and Devore and colleagues (2013) reported data from the prospective Nurses' health study. The initial age of the subjects ranged from 54-79 yr. Biennial reports classified habitual physical activity and identified 2355 cases of incident urinary incontinence. On comparing the highest versus the lowest physical activity quintiles (estimated energy expenditures of 28.6 vs. 6.2 MET-h/week), the odds ratio of developing leakage in the more active group was 0.81 (CI 0.71-0.93). Benefit was greater for stress than for urge incontinence. The main activity of the nurses was moderate walking, and there was a 26% reduction of risk for the quintile undertaking the most walking (odds ratio 0.74, 95% CI 0.63-0.88), with a probability of p = 0.01 for a trend. The body mass index was by far the most important risk factor in this population, with an odds ratio of 4.12 (Danforth et al., 2007; Devore et al., 2013). Townsend and colleagues also analyzed data from the Nurses health study. They noted that the relative risk of incontinence was attenuated by adjusting data for body mass index, and they suggested that the benefit of a physically active lifestyle probably arose in part from better weight maintenance in the more active individuals (Townsend et al., 2008).

Kikuchi and associates (2007) examined a mixed population of elderly men and women aged over 70 yr; 507 were continent, and 169 incontinent (an incontinence prevalence of 34% in the women, and 16% in the men). The odds ratio of incontinence relative to those who were inactive was 0.71 for the middle level of activity, and 0.58 for those with a high level of physical activity (Kikuchi et al., 2007).

Lee and Hirayama (2012) reported questionnaire and interview data for 700 men and 300 women of average age 66 yr. Incontinence was reported by 7.2% of the men and 27.5% of the women. A multivariate analysis showed that for those undertaking more than 1000 MET-min of walking per week, the risk relative to inactive individuals was 0.36 (0.14-0.92) in men and 0.43 (0.20-0.96) in women. However, the benefits were not statistically significant when classified in terms of reported moderate or total activity.

Sung, Kassis, and Raker (2012) collected data on 85 candidates for a urethral sling operation. Prior to their operation, activity averaged 396 MET-min/week, with 38 of the 85 taking what was judged an adequate amount of leisure activity (>500 MET-min/week).

Physical fitness and continence.

Moreno-Vicino and colleagues evaluated 471 non-institutionalized women aged >65 yr; 28.5% reported incontinence. The risk was linked to a high body mass index and body fat, and a low fitness index, with upper body flexibility being the most indicative element among fitness variables that also included muscle strength, balance and walking speed. Incontinence was also more likely in those with a lower daily volume of walking (Moreno-Vicino et al., 2015).

Yoshida and team (2007) examined 785 men and 1015 women aged 70 yr and older. The average prevalence of incontinence was relatively low (13.4% in the men and 23.3% in the women), but nevertheless a lack of fitness as shown by a low walking speed and poor nutrition were risk factors in the men, and obesity, a lack of physical activity and a poor mental state were risk factors in the women (Yoshida et al., 2007).

Fitness programmes and continence.

Six reports have demonstrated the benefits of participating in 4 fitness initiatives (Huang et al., 2011; Kim et al., 2011; Morrisoe et al., 2014; Smith et al., 2010; Yang et al., 2011); in at least one of the 4 trials, the decrease of incontinence was substantial (Kim et al., 2011).

A small 12-week trial compared Pilates dominated-exercises (n = 16) versus functional fitness training (low impact aerobic training and circuit training with 6 hydraulic resistance stations)(n =21)(Huang et al. 2011). The subjects were community-dwelling women with urinary incontinence who had become over-weight and unfit. Both interventions were effective in increasing upper and lower body muscular endurance, sit-ups and flexibility, but the Pilates programme gave a better improvement in body composition, and was more effective in correcting the incontinence (Yang et al., 2011).

About 15% of younger individuals recruited to a diabetes prevention programme initially reported urinary leakage when they engaged in sport or exercise, and 7% of younger women, a third of middle-aged women and a quarter of older women claimed to be avoiding sporting activities because of problems of urinary leakage (Brown and Miller, 2001). Participants were randomized to intensive lifestyle therapy (660), metformin treatment (636) or a placebo (661), and the prevalence of incontinence was re-evaluated after 2.9 yr. The lifestyle group, who undertook 150 min of moderate activity per week, had a better outcome than the other two groups, with respective final incontinence rates of 31.3, 39.7, and 36.7%. A multivariate analysis showed an advantage of the lifestyle intervention relative to placebo, with an odds ratio of 0.80 (CI 0.64-1.01)), due mainly to a reduction of body mass.

Kim and colleagues (2011) tested the effects of a biweekly 3-month multi-dimensional exercise programme in 61 elderly Japanese, aged ~ 79 yr; 31 women were assigned to the intervention group, and 30 to a control group. The exercise programme included chair, resistance-band and ball exercises, walking and balance exercises, and specific activities designed to strengthen the pelvic floor. The control group showed no change of incontinence, but in the experimental group the prevalence dropped substantially, from 66.7% to 22.3%, although subsequently rising to 40% over a 6-month follow-up (Kim et al., 2011).

Morrisoe and colleagues enrolled 328 Latinos aged 60-93 yr in a 1-year walking programme; initially, 17.4% were incontinent, with a trend linking leakage to a low pedometer step count. Gains of continence over the year related to gains in physical performance scores (OR 0.69 (0.50-0.95)), with associated improvements in the health-related quality of life score. In a larger sample from the same population, Smith et al. (2010) evaluated 441 women and 131 men, using the Yale physical activity index. The estimated weekly energy expenditure was not significantly related to incontinence (odds ratio 0.82 (0.35-1.90)), but the energy-cost weighted average of the time spent in various types of activity was inversely related to incontinence (odds ratio 0.77 (0.60-0.98)) (Morrisoe et al., 2014).

Strength of pelvic muscles and continence. The strength and functional capacity of the pelvic floor is one relevant aspect of personal fitness. This can be assessed by a variety of methods, including vaginal palpation, electromyography, manometry, dynamic ultrasound and magnetic resonance imaging (Raizada et al., 2010). Fatigue of the pelvic muscles seems a factor that can predispose to incontinence over the course of a bout of exercise, but the influence of regular physical activity and athletic participation upon pelvic floor function remains unclear. Several reports have suggested that the pelvic floor muscles can be strengthened by appropriate local training exercises (see treatment, below), but there are also investigators who maintain that excessive high-impact exercise, heavy lifting or a persistent cough can overload, stretch and weaken the ligaments and muscles of the pelvic floor, with a permanent or semi-permanent increase in the risk of incontinence (Bø, 2004; Borin et al., 2013; Brandão et al., 2015; Jørgensen et al., 1994; Nichols and Milley, 1978).

Burti et al. (2014) examined a sample of 56 women of average age 52 yr, 30 of whom were incontinent. The time to fatigue during repeated maximal pelvic floor muscle contractions was considerably shorter in those who were incontinent (9.1 versus 14.2 minutes). Re Ree et al. (2007) demonstrated the development of a similar fatigue in young athletes after a bout of strenuous physical activity. In those of their subjects who developed urinary incontinence, maximal post-exercise vaginal pressures as measured by a balloon were substantially lower than resting values. On the other hand, incontinence in a group of physical education students was unrelated to the strength of their pelvic floor muscles (Bø, Stien, and Kulseng-Hanssen, 1994).

Borin and colleagues (2013) compared the pressure developed by the pelvic floor when lying supine in 30 volleyball and basketball players and 10 controls. The athletes developed significantly lower pressures than the non-athletes. Moreover, the extent of urinary leakage was negatively correlated with the amount of athletic involvement, suggesting that repeated exposure to high impact stress may have had an adverse effect on the pelvic floor muscles (Borin et al., 2013).

A small-scale comparison of seven former high-impact athletes with seven controls found a lesser pubovisceral muscle thickness and a lesser ability to develop maximal voluntary pelvic muscle contractions in former athletes than in the controls (Brandão et al., 2015).

An occupational comparison between Danish nurses, who engaged in frequent bouts of heavy lifting and the general population of Denmark found that the odds ratio of requiring an operation for genital prolapse was 1.6 greater in the nurses (Jørgensen et al., 1994). Unfortunately, no data on the extent of urinary incontinence were provided, and it is possible that the nurses may have expressed more frequent complaints because they had a greater knowledge of problems and/or greater access to genito-urinary surgery than the general public. Further, the study was not controlled for possible differences of parity between the nurses and the controls.

Risk factors for incontinence

In statistical analyses of the association between physical activity and incontinence, it is important to include as covariates other major risk factors. Most studies of stress incontinence in young athletes concern nulliparous individuals, although parity is an important risk, and exercise is particularly likely to induce incontinence in the first few months following pregnancy (Wilson et al., 1996). The inherently lax joints that are essential for success in gymnastics may also predispose to leakage (Eliasson et al., 2002). The other main risk factors are age, constipation, obesity (commonly assessed as the body mass index), and a history of genitourinary surgery (Møller et al., 2000). A 5-unit increase in body mass index is enough to increase the risk of incontinence by 20-70% (Subak et al., 2009), and conversely some weight-loss interventions have been very effective in reducing the risk of incontinence (Vissers et al., 2914; Wing et al., 2010).

Incontinence also seems to be associated with eating disorders, possibly because an inadequate intake of nutrients leads to muscle weakness (Bø and Sundgot Borgen, 2001; de Araujo et al., 2008; Hextall et al., 1999). This could be one reason why incontinence is frequent in gymnasts and runners.

Some reports have suggested additional risk factors, including diabetes mellitus, hypertension and stroke, smoking, depression, overall functional impairment, the menopause and oestrogen deficiency, and the use of medications such as psychotropic agents, angiotensin converting enzyme (ACE) inhibitors, caffeine and diuretics (Abrams et al., 2009; Bump and Norton, 1998; Devore et al., 2013; Hannestad et al., 2003; Hunskaar et al., 2003).

Patho-physiology of urinary incontinence

The pelvic floor muscles normally maintain some tone, except when a person is voiding. The pelvic muscles are able to contract simultaneously, causing an inward lift and squeeze around the urethra, vagina and anus that can counter a sudden rise of intra-abdominal pressure (DeLancey, 1990). The pelvic floor muscles are usually "stiffer," and have a more cranial position in nulliparous and continent women than in those who present with urinary incontinence (Haderer et al., 2002; Peschers et al., 1996).

The influence of habitual physical activity upon the patho-physiology of urinary incontinence remains unclear, with some investigators arguing that regular exercise strengthens the muscles of the pelvic floor, and colleagues maintaining that excessive habitual physical activity can have a weakening effect (Bø, 2004).

Even the importance of the thickness of the pelvic muscles remains debatable. One small study found that at the level of the mid-vagina, the pubo-visceral muscles were thicker in female football players who showed incontinence than in those who did not (Da Roza et al., 2015b). Kruger and colleagues (2007) used 2- and 3-dimensional trans-labial ultrasound to underline that there was a larger hiatal area and a greater bladder neck descent during the Valsalva manoeuvre in athletes when 24 competitors were compared with 22 controls (Kruger et al., 2007). However, these same studies demonstrated a progressive increase in the average cross-sectional area and thickness of the levator ani and pubo-rectalis muscles among participants in high impact sports (Kruger et al., 2007; Kruger et al., 2005). This could reflect a local adaptation to repeated high impacts, but other possibilities include a selective retention in the study of individuals with an initially strong pelvic musculature, or a training-induced development of the foot arches that reduces the effect of a heavy foot impact upon the pelvis (Nygaard et al., 1996).

Leakage usually occurs in the latter part of competition or training sessions (Caylet et al., 2006; Eliasson et al., 2005), suggesting that fatigue is a factor, and if so, it seems likely that the onset of such fatigue could be delayed by a strengthening of the pelvic musculature. In support of the fatigue hypothesis, Ree et al. (2007) examined the effects of strenuous physical activity (90 min of interval training relative to 90 min of rest) in 12 nulliparous young women with mild stress incontinence. An intra-vaginal balloon catheter demonstrated a 20% reduction in mean contraction pressures immediately after the bout of interval exercise.

Treatment of stress incontinence

If the leakage is minor, some athletes find it sufficient to take simple immediate practical counter-measures, but if the problem is seriously disrupting athletic performance and overall quality of life, recourse may be made to a specific training of the pelvic muscles, biofeedback, medication, surgery and other forms of treatment that have varying efficacy (Table 3). It remains difficult to choose among a wide range of possible options, because there have as yet been few single- or double-blind trials in athletes.

Immediate counter-measures

Many authors have suggested the obvious simple counter-measure of urinating immediately before participating in a sport (Jácome et al., 2011). Some athletes also deliberately restrict their fluid intake, but this is an unwise measure, as it may put competitors at risk of dehydration-related injuries (Sherman et al, 1997). Another simple option is the insertion of an intra-vaginal tampon or sponge. One investigator found total dryness throughout 30 minutes of aerobic exercise when such a device was used by 6 women who had previously complained of stress incontinence (Glavind, 1997). The wearing of dark clothing has also been proposed as a means of dissimulating minor leakage.

Training of the pelvic floor muscles

Stress incontinence can apparently be reduced if the affected individual develops the ability to make a quick contraction of the pelvic floor muscles when a sudden rise of intra-abdominal pressure is anticipated, either from athletic effort or a cough (Bourcier, 2008; Miller et al., 1998). The idea is that a strong and well-timed contraction will compress the urethra, limit urethral descent and thus prevent leakage. The learning of this technique has not always been included in rehabilitation programmes, but nevertheless many athletes learn to make such a contraction instinctively when they are exercising, without specific training (Constantinou and Govan, 1981). Specific exercises to increase the strength of the pelvic floor muscles were first advocated by Kegel (1951), who claimed that 84% of cases of incontinence could be cured by such a programme. However, others have been more sceptical of their efficacy. A randomized study of 105 inactive primiparous women found that the inclusion of 8-12 maximal pelvic muscle contractions in a biweekly pregnancy fitness class did not reduce the incidence of urinary incontinence 6 weeks post-partum (Bø and Haakstad, 2011). Details of the Kegel technique have been reviewed by Bø (1994).

Table 3: Methods for the treatment of urinary stress incontinence.

Author	Sample	Treatment	Findings	Comments
Bø, Hagen et al. (1989), Bø et al., (1990)	52 women aged 45.9 yr with stress incontinence	8-12 pelvic floor max contractions, 3/day for 6 months, half of group also made sustained contractions 1/week	60% of intensive exercise, 17% of home exercise group almost continent after 6 months of treatment	Exercises much more effective if supervised. Associated gains of pelvic floor strength.
Bø et al. (1999)	107 women with stress incontinence, aged 49.5 yr	Pelvic floor exercises (25), electrical stimulation (25), vaginal cone (27), vs. controls (30)	Pelvic floor exercises superior to alternatives in terms of both strength & leakage	Exercises decreased average urinary leakage from 30 g to 17 g
Bourcier (1990)	68 young nulliparous women: 30 athletes, 38 active women, aged 22 yr	Applied biofeedback while in athletic posture, 2/week for 3 weeks, 1/week for 4 weeks	Both groups improved, but athletes not completely cured by treatment	Focus on ability to control pelvic diaphragm
Castro et al. (2008)	108 women aged ~ 56 yr, with stress incontinence (leakage > 3g with standard 200 mL bladder volume)	Comparison of pelvic floor exercises (31), electrical stimulation (30), vaginal cones (27) vs. controls (30)	Patients reporting satisfaction: 58, 55, 54 and 21% respectively	3 treatment options seem equally effective
Culligan et al. (2010)	62 women with little pelvic floor dysfunction	Pilates vs. pelvic floor muscle exercises	Equal increase of pelvic floor strength as measured by perineotomy	No discussion of incontinence
Fitz et al. (2012)	Stress incontinence, 16 women given biofeedback, 16 comparison group, aged 58 yr	3 sets of slow contractions, 3-4 fast pelvic floor contractions 2/wk for 6 weeks	Adding biofeedback improved power, endurance & speed of pelvic muscles, reduced urinary symptoms & improved quality of life	
Hirakawa et al. (2013)	46 women, aged ~ 58 yr	Half had biofeedback added to pelvic muscle exercises for 12 wk	No difference in amount or frequency of leakage	
Kashanian et al. (2011)	91 women	Pelvic muscle exercises, n = 50, supplemented with Kegelmaster, n = 41	Tests at 1 & 3 months show similar gains in both groups (incontinence, pelvic muscle strength, social confidence)	
Mørkved et al. (2002)	94 women with stress incontinence, average age 46.3 yr	Pelvic floor muscle training, half of group with added biofeedback	Cure (2g leakage or less) in 69% of group with biofeedback, 50% in comparison group	Effect of biofeedback not statistically significant
Nygaard et al. (1996)	71 women aged ~ 53 yr with urinary incontinence	3 months pelvic muscle training	Stress incontinence decreased from 2.5 to 1.4 times/day among those completing treatment (56% of enrollees)	No additional benefit from audio-tape giving detailed instructions
Ong et al. (2015)	Women aged > 18 yr, 21 experimental, 16 controls	16 wk pelvic muscle training, supplemented by biofeedback from Kegel vibrance device.	Biofeedback increased pelvic muscle strength, but no difference in cure rate of 62%	
Pereira et al. (2012)	45 women aged ~ 65 yr randomized to vaginal cones, pelvic muscle training & control groups	Pad leakage & intravaginal pressures	Both treatments reduced pad leakage to near zero & yielded similar increases of intravaginal pressures	
Quartly et al. (2010)	28 women aged 18-58 yr	Perineometer	Max. strength of perineal muscles influenced by parity, endurance correlated with age	

Table 3 continued.

Author	Sample	Treatment	Findings	Comments
Sung et al. (2012)	85 incontinent women aged ~ 49 yr who underwent sling surgery	Questionnaire estimate of habitual activity	Increased from 396 to 693 MET-min/wk 6 months post-surgery	
Wyman et al. (1998)	145 women with stress incontinence, bladder training vs. pelvic muscle exercises & biofeedback or combination	6 weely office visits followed by 6 weeks of telephone calls	Combination treatment gives best immediate results in terms of incontinence & quality of life, but no inter-group difference at 3 months	

A typical Kegel routine involves sustaining maximal contractions for 6-8 s, possibly with 3-4 sets of 8-12 slow-velocity supervised contractions practiced 3 times per week, for as long as 6 months. Exercises of this type are certainly the simplest therapeutic approach, and given alone or in combination with behavioural therapy, they probably offer the most appropriate type of treatment for athletes who wish to correct small to moderate amounts of urinary leakage (Burgio, 2013; Hay-Smith, Bø, and Berghmans, 2001). It may take a few weeks to learn the correct technique, and adherence to the training programme is important to the success of treatment. Moreover, because intra-abdominal pressure levels can reach higher levels in athletes than in inactive individuals, a more rigorous exercise programme is needed for those who are engaged in high-impact sports (Bø, 2004).

Many studies have claimed benefit from pelvic muscle exercises in the general population (Bø, 1994), with self-assessed incontinence cure rates of 32-84%, and corresponding gains of self-esteem (Kargar Jahromi,Talebizadeh, and Mirzaei, 2014). Several uncontrolled trials have also found this approach to be helpful in elite athletes. A recent Cochrane review of 21 controlled trials (Dumoulin, Hay-Smith, and Mac Habée-Seguin, 2014) supported the use of pelvic muscle exercises as the first line of treatment, with a "cure rate" of 56%. This was 8 times greater than the change seen in controls, although the report noted a need for further research on the long-term effectiveness of pelvic exercises, and it did not address the issue of incontinence in athletes.

Bø and colleagues (1989; 1990) found that after pelvic floor muscle training,17 of 23 women with stress incontinence reported improvements during jumping and running, and 15 noted improvements during lifting. These subjective findings were confirmed by a decrease of pad leakage from an average of 28 g to 7.1 g. Improvements were significantly greater in those exercising with an instructor for 45 min once per week than in those assigned to a home exercise programme. Da Roza et al. (2012) arranged pelvic muscle training for 16 young sports students who had complained of sporadic urinary incontinence. Unfortunately, perhaps because of the time demanded by the training programme (60 minutes per session), only seven of the 16 students completed the 8-week programme. In these seven individuals, the pelvic floor muscle strength was increased, with increases of intra-vaginal pressures, and the frequency and volume of incontinence was dramatically reduced.

The need for, and the optimal format of training supervision, remain controversial topics. An audit of NICE guidelines on ante-natal pelvic floor exercises found that most women were aware of the need for such exercises, only a minority had the correct information on technique, and few practiced such training on a regular basis (Ismail, 2009). A Cochrane Review concluded that in general functional improvement was greater with regular (for example, weekly) health professional contact (J. Hay-Smith et al., 2012). One report also found benefit from a pelvic floor fitness class taught by lay leaders (Brubaker et al. 2008).

On the other hand, Nygaard and colleauges (1996) observed that the provision of audio-tapes with detailed exercise instructions did not improve upon the basic benefit women aged ~ 53 yr obtained from untutored pelvic floor exercises. Ahund et al. (2013) also noted that if women were given written instructions, home-based training was just as effective as a programme that was reinforced by a follow-up visit from a health professional every 6 weeks.

Yoga, Pilates classes and other exercise interventions have their advocates as a means of treating incontinence (Huang et al., 2011)(above), but they do not seem to have any specific effect in activating the pelvic floor muscles or elevating the bladder neck (Baessler and Junginger, 2010), nor do they offer any greater increase in pelvic muscle strength relative to more specific local muscle training (Culligan et al., 2010). A review of 3 controlled trials of abdominal muscle training, 2 of the Paula method and 2 of the Pilates method found no advantages relative to standard pelvic muscle exercises (Bø and Hebert, 2013). The same review noted that there had as yet been no randomized trials of the efficacy of yoga, Tai Chi, or general fitness training.

Biofeedback. A growing number of authors have examined the value of combining biofeedback with pelvic muscle exercises. Many of these interventions have been made with athletes in the supine position, but Bourcier (1990) carried out the combined training with competitors standing in positions typical of their sport. Lee and colleagues further demonstrated that extracorporeal feedback was just as effective as the use of intra-vaginal sensors, and was more comfortable for the subjects than an intra-vaginal device. However, the objective "cure" rate of 52% seen in their 12-week programme was similar to what others have found with pelvic muscle training alone (Lee et al., 2013). Of six other studies, five found no advantage of biofeedback alone or combined with pelvic muscle training relative to standard pelvic exercises (Castro et al., 2008; Hirakawa et al., 2013; Kashanian et al., 2011; Mørkved et al., 2002; Ong et al., 2015; Rivalta et al., 2010). However, in the sixth trial, significant gains were observed with combined interventions (Fitz et al., 2012).

Castro and associates (2008) made a comparison between pelvic floor exercises (31 subjects), electrical stimulation (30 subjects), use of vaginal cones (27 subjects) and controls (30 subjects) in older women (aged ~ 56 yr). In this study, the 3 treatment options seemed to be equally effective, with levels of satisfaction of 58, 55, 54 and 21% reported respectively for the 4 groups (Castro et al., 2008).

Hirakawa and colleagues (2013) studied 46 women aged ~58 yr. At the end of a 12-week trial, they saw no inter-group difference in the amount or frequency of leakage between those receiving combined therapy and those simply performing pelvic muscle exercises.

Kashanian et al. (2011) compared the response to pelvic muscle exercises (n = 50), or such exercises supplemented by biofeedback from a Kegelmaster device (n = 41) in women aged ~ 40 yr. Episodes of incontinence ranged from mild (1-2/month) to severe (more than 5 times/day). At 1 and 3 months both groups showed similar improvements in terms of incontinence (with a third completely cured, and another third having incontinence only 1-2 times/month. Both groups also showed similar gains in pelvic muscle strength, and social confidence.

Mørkved et al. (2002) reported a stress incontinence cure-rate of 69% when biofeedback was used to supplement assisted pelvic muscle training in a half of a group of 94 women with a mean age of 46.6 yr. Those receiving standard pelvic muscle training reported a trend to a slightly lower cure-rate of 50%, but there was no statistically significant difference between the two interventions.

Ong and colleagues assessed the effects of adding biofeedback from a Kegel device relative to standard pelvic muscle exercises in women aged ~ 51 yr; 21 remained in the experimental group, and 16 of 19 completed the control programme. Incontinence was already reduced at 4 weeks, and after 16 weeks, the incontinence "cure" rate of 62% was similar for both groups, although those receiving biofeedback showed a greater increase in pelvic muscle strength (Ong et al., 2015).

Rivalta and coworkers (2010) treated three nulliparous female athletes with an uncontrolled intervention that combined pelvic floor muscle training with biofeedback, electrical stimulation and the use of intra-vaginal cones. A 3-month programme abolished the previous incontinence in this entire small sample (Rivalta et al., 2010).

Fitz and coworkers (2012) completed the 1 trial where biofeedback significantly enhanced the effect of pelvic muscle exercises alone. The standard pelvic muscle training (3 sets of slow contractions, 3-4 fast pelvic floor contractions 2/week for 6 weeks) was administered to a half of their subjects (n = 16), and for the other16 subjects biofeedback was added to the standard intervention. Relative to the standard treatment, those receiving the biofeedback demonstrated improved power, endurance and speed of contraction in their pelvic muscles, with reduced urinary symptoms, less restriction of daily physical activity and an improved quality of life (Fitz et al., 2012).

Medication. Mood-changing drugs such as the anti-depressant imipramine and the serotonin and norepinephrine uptake inhibitor duloxetine have improved the quality of life for some people with incontinence (Cardozo et al., 2010), but the use of these drugs does not seem to have been tested specifically in athletes (Corcos et al., 2006), and a Cochrane review found the effect on urinary incontinence was only slightly greater than that of a placebo (Mariappan et al., 2005).

Athletes must be careful that any drugs they may take do not transgress anti-doping regulations. Anticholinergic drugs may offer some benefit, but they are not recommended for athletes because of the concomitant reduction of sweating.

Surgery. Interventions such as pubo-vaginal sling procedures, retropubic suspension and periurethral injections can be offered to older patients when other treatments have failed, although they are inappropriate for young athletes who are only experiencing mild incontinence when they engage in high intensity sport (Bø, 2007).

One report studied 85 women aged ~ 49 yr who had undergone mid-urethral sling surgery, finding that an improvement of continence was associated with a post-operative increase in leisure energy expenditures, from an average of 396 to 693 MET-min/week (Sung et al., 2012).

Other treatments. Other proposed treatments of incontinence have included electrical or mechanical stimulation of the perineal muscles (Lauper et al., 2009). In a small randomized controlled trial (15 women aged ~ 65 yr per group), Pereira et al. (2012) claimed that the use of vaginal cones was as effective as pelvic muscle training, both in terms of reducing urinary leakage to near zero and in yielding similar increases of intra-vaginal pressures.

Areas for future research

An important first step in future research on this topic will be to develop improved non-invasive methods of assessing urinary incontinence, devising well-standardized questionnaires that yield assessments of leakage that are closely related to objective measurements made by changes in the mass of perineal pads. There remains a need for high-quality research where the risk of incontinence is compared between athletes of well-defined abilities and well-matched control groups. Such studies should define not only the extent of incontinence, but also its impact upon the individual's competitive performance and quality of life. Given that leakage is more frequent during training than in competition, it would be interesting to correlate leakage with catecholamine levels.

The apparent difference in the risk of leakage with crew position in military aircraft is intriguing, and merits further investigation. The association of incontinence with eating disorders is also interesting; does this simply reflect muscular weakness in an under-nourished group, or is there a more profound effect from the reduced levels of oestrogens in those with eating disorders? In this context, there is a need to explain the association of incontinence with a low body mass in sports such as soccer, where there is not normally any trend to eating disorders.

The risk of high impact sports seems to increase with training volume and with years of training, and it should be clarified whether this simply reflects a progression to physically more demanding manoeuvres or whether there is cumulative damage from involvement in high-impact sport. Further observations on those involved in parachute jumping might clarify the frequency and extent of jumping-related injuries.

Available data support the use of pelvic muscle exercises as the first line of treatment, with a high immediate "cure" rate of 56%. However, further research is needed on the response in athletes, and on the long-term effectiveness of pelvic exercises. The importance of the thickness of the pelvic muscle floor also remains to be clarified. Should treatment attempt to increase the thickness of the pubo-visceral muscles, and should one encourage such a development in athletes? Finally, many young women seem unaware that the problem of urinary leakage can be helped by pelvic floor muscle exercises; there is scope to document this lack of practical knowledge, to understand the underlying reasons, and to examine methods of making preventive interventions more widely accepted.

Practical applications and conclusions

It is clear from this review that a minority of athletes can develop substantial urinary incompetence in a variety of sports, particularly during high-impact activities. Moreover, this can have a negative influence upon motivation and performance. Further, similar problems can arise in the general population, particularly after childbirth and in old age, discouraging those who are affected from reaching minimum recommended levels of daily physical activity. Often, embarrassment limits disclosure of the problem. However, there are now objective techniques that can be used to monitor the extent of leakage during various types of physical activity and to form practical recommendations for treatment. A moderate level of habitual physical activity seems to play a useful preventive role in the general population. Slight and infrequent leakage can usually be countered by wearing a perineal pad. Many with more substantial leakage can be greatly helped by a sustained programme of pelvic floor muscle exercises, and the response to such an intervention should be evaluated before weighing the need for medical or surgical options.

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Author's qualifications

The author's qualifications are as follows: Roy J. Shephard, C.M.; Ph.D., M.B.B.S., M.D. (Lond.), D.P.E., LL.D., D.Sc., FACSM, FFIMS.

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