Journal of Bodywork and Movement Therapies (2005) **9**, 99–108

Journal of
Bodywork and
Movement Therapies

www.intl.elsevierhealth.com/journals/jbmt

FUNCTIONAL PATHOPHYSIOLOGY

Does lumbo-pelvic dysfunction predispose to hamstring strain in professional soccer players?

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Received 5 March 2003; received in revised form 1 February 2004; accepted 30 March 2004

KEYWORDS
Cybex norm dynamometer;
Trunk flexion–extension;
Biomechanical chain;
Manual assessment;
Lumbo-pelvic rhythm;
Hamstring strain;
Professional soccer players

Abstract *Purpose*: It has been reported that hamstring strain in athletes is commonly followed by subsequent hamstring strains (Am. J. Sports Med. 30(2) (2002) 199). The current management of these injuries is oftentimes unsuccessful and may plague the athlete throughout their sporting career. The aim of this study was to test the hypothesis that hamstring strain can be a "symptom" secondary to dysfunction in other parts of the same biomechanical chain. For reasons explained below, the functionality of the lumbo-pelvic mechanism was selected for assessment in a retrospective double-blinded randomized controlled experimental design. A by-product of the research methodology was the discrimination of predictive value between manual and machine assessment techniques.

Methods: Five professional soccer teams sent 20 players with and without histories of hamstring injury for assessment of their lumbo-pelvic mechanisms (subjects = 20, of which 15 were Hamstring group and 5 were controls, i.e. one control from each club). Each player followed the same procedure; first, their lumbo-pelvic mechanics were manually assessed using a standardized evaluation by the same blinded manual therapist; second, each player was assessed on a Cybex Norm dynamometer for trunk flexion–extension values. The data were analysed, and subsequently, the medical histories of the players were revealed.

Results: Manual assessment revealed higher levels of lumbo-pelvic dysfunction in the hamstring group—particularly in players with recurrent strains (though not statistically significant). Cybex assessment appeared to be less sensitive than manual assessment. However, for subjects who had a greater time period out of competitive play, the dynamometry was more sensitive; indicating its use in assessing deconditioning syndromes. There was no statistical correlation between manual and dynamometer assessment results. Statistical evaluation proved insignificant, but was hampered by low subject number, and more importantly by lack of normative data and contamination of the control group.

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doi:10.1016/j.jbmt.2004.03.005

Conclusion: Further research is required to provide statistical validity for this clinically acceptable and highly evidenced hypothesis: *hamstring strain can be associated with lumbo-pelvic dysfunction*.

Introduction

"Hamstrings"

Such is the notoriety of the hamstrings that, as well as being a noun collectively describing the group of muscles in the posterior compartment of the thigh, "to hamstring" is also a verb. To hamstring, is to cripple or prevent the activity or efficiency of a person or enterprise (Tulloch, 1993).

Hamstring injury incidence

Hamstring strain is one of the most common injuries in sports that involve sprinting (Turl and George, 1998; Whiting and Zernicke, 1998; Pollard and Quodling, 1999; Askling, 2000; Verral et al., 2001). In the 1996 Olympics, hamstring injury accounted for 51% of all lower limb therapy issued at the Olympic Sports Medicine Clinic (Nannini et al., 1997). This indicates that it is most common injury across a range of different sporting activities and therefore is arguably the muscle group with the greatest vulnerability (Fig. 1).

The susceptibility of the hamstrings to recurrent strain is well documented (Croisier et al., 2002; Orchard and Seward, 2002). Verral et al. (2001) found that a previous history of hamstring injury was the single most significant factor in hamstring strain susceptibility, with previously injured players having 4.9 times the risk of those with no history. Orchard and Seward (2002) studied the epidemiology of Australian Rules Football injuriesfound them to be comparable to soccer. They discovered that hamstring injuries had the highest recurrence rate of all injuries, at 34%. Given the fact that they are very metabolically active tissue, muscles, such as the hamstring group, are invariably well perfused with blood vessels. It would seem unlikely therefore, that the mechanism for repetitive strain is due to poor or inefficient healing mechanisms within the hamstring itself, despite scar tissue often being cited as causative in recurrent problems (Verral et al., 2001). If this logic was good, muscle strain in other tissues, such as the quadriceps group, would result in scar tissue formation and repetitive quadriceps strain; however, this is not observed clinically, nor in the literature. Hamstring strain has often been blamed on the biarticular nature, however there are many biarticular muscles, such as the rectus femoris, gracilis, sartorius and adductor magnus, yet none are subject to the same level of injury as the hamstring group. Instead, the high incidence of recurrence suggests either an inherent susceptibility of the muscle group to injury, or mismanagement/ineffective treatment of the initial injury. Furthermore, it may point to an injury mechanism external to the muscle itself.

Biomechanical principles dictate that restriction or tension in one part of a kinetic chain will create increased load on other parts of that same chain (Comerford and Mottram, 2001; Sahrmann, 2000). This may result in instant macrotrauma, or more likely, the cumulative effect of increased load is repetitive microtrauma, culminating in eventual strain. It was hypothesized that the recurrent nature of hamstring strain could be the result of tension or restriction elsewhere in the same functional chain of muscles.

To analyse the entire kinetic muscular chain, of which the hamstrings are a component, would be an infinitely complex task. For the purposes of this study, the lumbo-pelvic region was selected for assessment due to its close anatomical and functional relationship with the hamstrings, highlighted by their role in the lumbo-pelvic rhythm and the hip extensor mechanism (Magee, 2002; Chek, 1993/2002).

It was important to incorporate assessment methodologies that both maximized the objectivity of assessment and allowed a level of useful clinical carry over. Use of a Cybex Norm trunk extension flexion (TEF) unit was therefore chosen to provide the level of objectivity required. A standardized manual assessment incorporating common clinical screening methods was also utilized (described below). This latter more subjective assessment was justified on three fronts:

1. it provided information with good clinical carryover. Most clinicians will not have access to Cybex Norm TEF devices in their place of work. (At time of testing, this was the only TEF device on mainland UK.)
2. it provided a useful cross-reference to the dynamometry results.

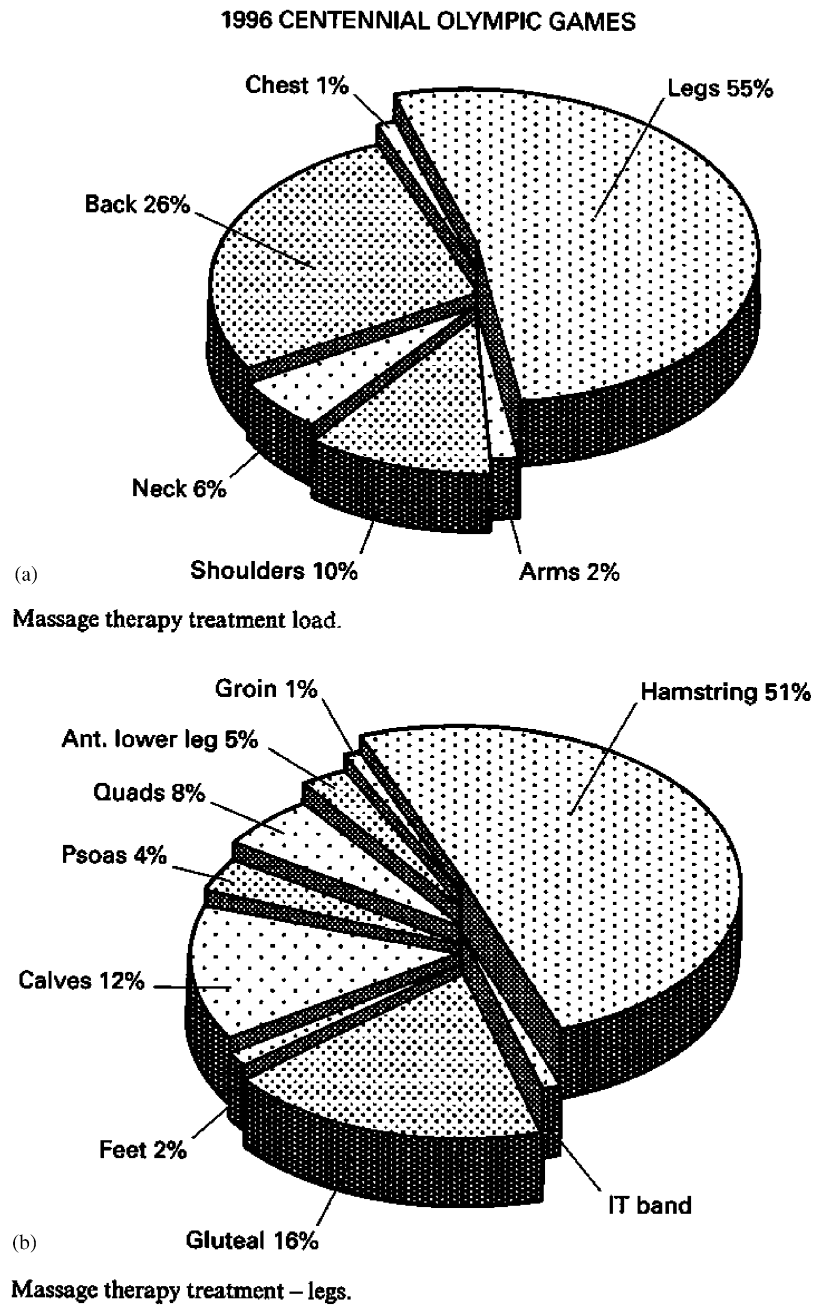

Fig. 1 Incidence of treatment given to (a) upper versus lower body (b) lower limb, Olympic Games, Atlanta, 1996 (Nannini et al., 1997).

3. this is an area in the literature in which standardized protocols are lacking.

Methods

Subjects

Twenty male professional soccer players (mean age 22.42 [control group mean: 22.20, hamstring group mean: 22.57]) from 5 London clubs were sent for testing by their club therapists. The therapists were aware of the nature of the testing and were instructed to send an experimental group of players with a historical or current hamstring strain, plus a minimum of one control player with no such history. This meant that the examiner was unaware of the number of subjects versus controls. A post-experimental questionnaire revealed that just one control was sent from each club meaning for the

Fig. 2 The Cybex Norm Dynamometer: (a) concentric extension, (b) concentric flexion.

hamstring group $n = 15$, and for the experimental group $n = 5$. The players were only informed of the nature of the testing, not what they were being tested for. This effectively blinded them. One player from the hamstring group ($n = 14$) withdrew from testing when he realized the maximal nature of the Cybex trunk flexion–extension assessment (Fig. 2).

Procedure

All players followed the same procedure: they were briefed on the entire testing procedure, and were asked to complete written medical history and informed consent agreements. Immediately prior to assessment, subjects warmed up for five minutes on a cycle ergometer, then did gentle stretches to the hip and trunk flexor–extensor muscle groups, consistent with previous dynamometry studies (Byl and Sadowsky, 1993; Nancy et al., 1993; Dvir, 1997; Hutten and Hermens, 1997; Croisier, 2002).

Design

The experimental design for the dynamometry was relatively easy to develop due to pre-existing literature and therefore methodology. The design of the manual assessment however was more difficult for the converse reason. Development of a reproducible assessment protocol had to be based on logical progression through the literature.

The objective of the research was to identify a level of *somatic dysfunction*, as defined in the international classification of disease (Stone, 1999), in the lumbo-pelvic regions of soccer players with a history of hamstring strain. The definition of somatic dysfunction therefore needed to be evaluated to guide the design of the procedure:

Somatic dysfunction

> *Impaired or altered function of related components of the somatic (body framework) system: skeletal, arthroidal, and myofascial structures and related vascular, lymphatic, and neural elements (DiGiovanna, 1991; Kappler, 1997, 2002).*

The osteopathic diagnostic criteria for discerning dysfunction through palpatory and observatory skills are to seek:

1. Tissue texture abnormalities.
2. Asymmetry (static, motion, tonicity, turgor, colour, temperature).
3. Restriction of motion.[2]
4. Tenderness (Kappler, 1997).

[2] *Note*: Hypermobility as a clinical entity is not incorporated into the diagnostic criteria for somatic dysfunction (Kappler, 2002).

Furthermore, according to Jones (1997), for a diagnosis of dysfunction to be made, any *one* of the four diagnostic criteria needs to be present.

The significance of this definition is that dysfunction can be present without the presence of painful symptoms that a soccer player may report. For a player to report an injury, they must presumably be suffering pain. For a player to have dysfunction of a somatic or "body tissue" (a somatic dysfunction), such as the lumbo-pelvic soft tissues, they need not be suffering pain. This is important, from the point of view that *somatic dysfunction* has not been previously investigated in soccer players—all studies to date have reviewed injury incidence. Hence many players will continue to play, unaware that they have a dysfunction. The first sign of this may only be when a painful injury occurs; the most common of which is hamstring strain.

The design of the manual assessment needed to therefore incorporate procedures to discern the four diagnostic criteria: tissue texture abnormalities; asymmetry; restriction of motion; tenderness (see Fig. 3). In addition to this, the findings from these tests needed to be standardized.

Assessments which rely on the palpatory skills and clinical opinion of a physician are wide open to subjective bias. However, the inadequacies and strengths of such research are debated in the discussion and covered in some depth in the literature (for example, Laslett, 1997; McPartland and Goodridge, 1997, Vincent-Smith and Gibbons, 1999).

Individual analysis of manual tests to evaluate accuracy, nearly always shows poor to mediocre degrees of reliability (Vincent-Smith and Gibbons, 1999; Laslett, 1997). In clinical practice however, a single test would never be used to make a diagnosis. A picture of what is happening in specific tissues and joints is built by gathering composite evidence from a range of assessment methods (Chaitow, 1997). An experimental design which combined a series of manual assessment techniques is what would provide the most accurate (reliable) picture of the players' lumbo-pelvic function. For further details see Box 1.

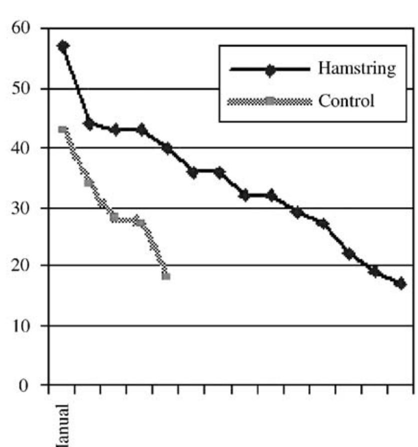

Fig. 3 Graph to show the mean Manual Assessment points scored in players with hamstring history, compared to those with no history of hamstring strain.

The subjects were tested in a randomized fashion. After the assessment procedures were completed and the data analysed, the club therapists were contacted to reveal which subjects were controls and which had a history of hamstring strain. The experimental procedure was therefore a retrospective double-blinded, randomized controlled trial.

Dynamometry: Each subject ($n = 19$) partook in a standardized dynamometry procedure on a Cybex Norm Trunk Extension/Flexion dynamometer at the British College of Osteopathic Medicine, London. None of the subjects had any experience of trunk dynamometry, though most had used a dynamometer for measurement of thigh strength, thus there was no discrepancy in performance due to a previous learning effect.

Motivation levels between subjects were considered consistent for two reasons: First, all were professional soccer players—therefore inherently had a competitive nature. Second, all testing was carried out in the presence of at least one other team mate who, without exception, provided encouragement and stimulated the competitive nature of the subject being tested.

The dynamometry protocol was as follows:

All assessment was isokinetic, using a concentric:concentric (flexion:extension) protocol.

The procedure can be summarized as:

4 *X* trial reps at 60°/s, 120°/s, 150°/s, 60°/s,
4 *X* experimental reps at 60°/s, 120°/s, 150°/s, 60°/s.

Subjects were routinely coached on technique and given 4 trial repetitions prior to 4 experimental reps at each of the speeds.The retesting of the subjects at 60°/s was done to allow the Average Points Variance (APV) to be calculated. The APV is sensitive to possible suboptimal effort (Brady et al., 1994) and an APV variation of greater than 20% is suggested as indicative of such suboptimal effort rendering the results unreliable (Dvir, 1997).The speeds were selected based on the result of previous studies and meta-analyses which declared that higher speeds (usually >150°/s) produced inconsistent and inaccurate results (Delitto et al., 1991; Reid et al., 1991; Byl and Sadowsky, 1993; Newton and Waddel, 1993; Brady et al., 1994) and for the following assessment reasons:

Speeds	Rationale
60°/s	slower speeds are less functional, but provide more accurate torque ratios, common speed used by other researchers,
120°/s	faster speeds are more functional, common speed used by other researchers,
150°/s	faster speeds are more functional, still below threshold described for inaccuracy, above the 120°/s threshold described for "extensor drop off" phenomenon to occur in dysfunctional low backs, common speed used by other researchers.

The range of movement (degrees from standing):

Flexion 80° needed more than 77° to assess angle of peak extensor torque.
Extension 5° more than 5° was uncomfortable for some subjects in pilot testing, especially when testing maximal effort.

Players were given consistent and firm verbal encouragement throughout, as described by CYBEX (1995–96). For further discussion on flexor extensor ratios, peak torque and extensor drop-off phenomenon please see Beimborn and Morrissey (1988); Reid (1991) and Kumar et al. (1995).

Manual assessment

Following the warm-up, and dynamometry, a standardized orthopaedic assessment (see Box 1) was performed by a solitary, blinded examiner as intra-examiner precision has consistently been shown to be greater than inter-examiner reliability (Vincent-Smith and Gibbons, 1999). In this study, the examiner observed for tenderness, asymmetry, restriction of joints and tissue texture changes (TART), as described in the definition of "somatic dysfunction" (Kuchera et al., 1997). The grading system used to record the results of provocative tests was described by Magee (2002) and is detailed below in Box 2 (Wallden, 2000). The grading system used to record palpatory range of motion (ROM) assessment, based on a similar design to Magee (2002), is described in Box 2.

This grading system allowed a cumulative, ordinal score to be calculated from each subject's orthopaedic examination. Each positive finding was given equal point weighting, and the grading system shown in Fig. 4 above established the number of points "scored", based on ROM or pain response. Therefore, the greater the subject scored, the greater their level of lumbo-pelvic somatic dysfunction. The original nature of this research inherently required the development of a scoring system, and with no normative data, these figures were calculated based on the results of this sample. This is acknowledged by the author as a likely source of bias; albeit favouring the null hypothesis.

Results

The manual assessment revealed some level of dysfunction (based on the TART criteria) at every subject's lumbo-pelvic spine. The Cybex however was more discriminatory, identifying dysfunction in approximately one-third of subjects. The hypothesis,

Box 1 Outline of blinded manual assessment of the lumbo-pelvic spine in sample group

Procedure:
Standing assessments: (1) standing observation (asymmetries), (2) SIJ forward flxn (3) Gillet's (4) Trendelenburg, (5) Ischial tuberosity test, (6) lumbar AROM, (7) Kemp's (8) Axial distraction

Seated assessments: (1) SIJ forward flexion, (2) Slump test

Supine assessments: (1) SLR, (2) SIJ distraction, (3)Fabere Patrick's, (4) Leg-length discrepancy (5) SIJ PROM

Side-lying assessments: (1) Lumbar PROM; flxn/extn, rotn/lat flxn (2) SIJ compression

Prone assessments: (1) Nutation/Counternutation (2) P-A compression (3) Palpation findings* (4) Leg-length discrepancy

Comments
**Acute*: warm, moist, red, inflamed, hypertonus, spasm, boggy, oedematous, congested

Chronic: cool, pale, hypotonic, contracture, reduced ROM, ropy, stringy, fibrotic, doughy, contracted, pimples, dry, folliculitis, pigmentation

Box 2 Grading systems used to locate somatic dysfunction using manual assessment

Pain		*Score*
Grade 0	patient reports no pain	0
Grade I	patient complains of pain	1
Grade II	patient complains of pain and winces	2
Grade III	patient winces and withdraws the joint	3
Grade IV	patient will not allow palpation of the joint	4
	(Magee, 2002)	
Range of motion		
0	Normal—no motion restriction	0
1	slight motion restriction	1
2	motion restriction	2
3	severe motion restriction	3
4	Ankylosed (no palpable motion)	4

that lumbo-pelvic dysfunction predisposes to hamstring strain, was unproven. However, a number of factors in the experimental outcome (reviewed in Discussion), and in the literature strongly support this notion.

What was proven was that manual assessment and Cybex dynamometry of the lumbo-pelvic region could not accurately be used to predict which players had suffered hamstring injury. However, given the retrospective nature of the study, and the fact that lumbo-pelvic dysfunction will not be significant in every hamstring injury, it was not reasonable to expect that either technique would demonstrate a full correlation.

Manual assessment

According to the interpretation used, the manual assessment results were as follows:

Hamstring group	Control group
57	43
44	34
43	28
43	27
40	18
36	
36	
32	
32	
29	
27	
22	
19	
17	

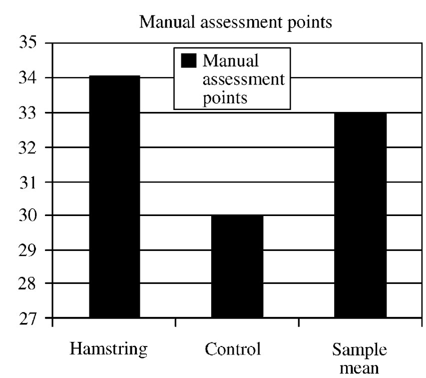

Fig. 4 Graph to show difference in the manual points assessment between hamstring and control groups. The sample mean (33.00 points) was used as the critical value above which the subject was considered to have significant lumbo-pelvic dysfunction, and below which the subject was considered to be within normal limits.

The mean manual assessment points scored for hamstring versus control groups were as follows:

Group	Points/no.	Mean points
Hamstring group	477/14	34.07
Control group	150/5	30.00
Total	627/19	33.00 (the "critical value")

By simply reviewing the data, it can be seen that there is no significant variation between the hamstring and control groups.

There was little difference found between the average points in each group. The small sample number may have influenced the outcome in either direction. In addition, four out of five control subjects were revealed to have a history of lumbo-pelvic dysfunction. Given this knowledge, it is not surprising that there was little difference in the findings between the groups. Since there are no previous studies conducted using this real-world clinical approach, there are no historical discriminators or markers for lumbo-pelvic dysfunction in this or any other group. This research therefore, sets a baseline.

However, rather than devaluing the research, the finding that 80% of the control group had a history of lumbo-pelvic dysfunction favoured the hypothesis that such low back dysfunction is associated with hamstring strain. Despite this lumbo-pelvic dysfunction in the controls, the hamstring group still had a higher mean lumbo-pelvic dysfunction score. This is therefore of greater significance than if the controls were without a history of lumbo-pelvic dysfunction. The significance of this increases further, since it would not be expected that *all* hamstring strains are the cause of lumbo-pelvic dysfunction.

Dynamometry assessment

As common sense would dictate, dynamometry results suggested that this form of assessment had greater sensitivity to players who had been out of training for the longest period of time. This finding is consistent with the more common use of this measurement device to detect a true "deconditioning syndrome" in injured workers involved in litigation battles. Dynamometry has offered a relatively objective means of detecting those who truly are deconditioned due to their ongoing injury, and those malingerers who masquerade as injured for financial gain (Mayer et al., 1994).

There were three main parameters used to assess the players:

(1) Angle of peak extensor torque.
(2) Extensor drop-off at $>120°$/s.
(3) Flexor:Extensor strength ratios.

For the participants' lumbo-pelvic spines to be recorded as dysfunctional two of the three parameters had to produce a positive result.

Six of the 19 subjects (32%) were considered to have dysfunctional lumbo-pelvic spines, based on the Cybex assessment alone. Of these six subjects three had been out of competitive play and training for between 3 weeks and 6 months; thereby implicating a deconditioning syndrome in these players.

Correlation of manual assessment results with Cybex results

There was no correlation between the results obtained from the two different forms of assessment. Only two of the six positive Cybex results (subjects 1 and 12) were paralleled by high manual assessment scores. The remaining four positive Cybex subjects had middling to low (i.e. by our definition "functional") manual assessment scores; creating poor agreement between the tests.

Discussion

One of the problems inherent in having a small sample of soccer players (including only one true control subject) was having little frame of reference to compare normal (functional) with abnormal (dysfunctional) results. One way to address this was by looking at norms within the group.

All four markers of somatic dysfunction were felt to be of equal import, as they are all utilized in routine clinical practice. It was recognized that within normal asymptomatic populations, individuals would have a basal level of dysfunction, as no one is symmetrical, for example. Calculating the subjects' mean scores was one way to create a critical value above which subjects' lumbo-pelvic spines could be considered dysfunctional, and below which lumbo-pelvic spines could be considered within normal limits.

If anything, this arbitrary figure (the mean score) would favour the null hypothesis, as nearly 95% ($n = 18$) of the group had a history of lumbo-pelvic dysfunction.[3] This figure is above general population figures for low back pain (80% lifetime incidence) (O'Sullivan, 2000)—compared with 94.74% in a sample whose mean age was 22.45 years, and well above the expected level of lumbo-pelvic dysfunction in this age group. If a figure greater than the mean of this cohort was achieved it was therefore safe to say that this subject had greater somatic dysfunction than his sample group and therefore others from the same general population.

Of course the inter-rater reliability of many of the assessments used is known to be poor; therefore it is impossible to say whether other examiners would achieve a similar result. Nevertheless, without an original study, there is no baseline to work from.

Despite use of the sample mean (33.00 points) as the critical value, favouring the null hypothesis, it was still evident that the hamstring group had higher somatic dysfunction scores; though these were not statistically significant.

[3]If an asymptomatic population had been used to establish an arbitrary figure using the same methods, a far lower score would presumably arise as the critical value.

The degree of tenderness was rated by the subject being assessed (as described by Magee, 2001), and therefore was open to their own subjective bias; this could not be accounted for within the experimental design, and besides, in a real world situation would be a reflection of how each subject responded to their physiological state and environment at that time. Trying to exclude this as a bias, would sterilize the testing procedure to the extent that it would be unrepresentative of what the individual was experiencing. Pain (which is well known to not be objective, nor standardized) can be a very real part of the injury and rehabilitative experience and should not be ignored because it is difficult to measure.

The passive ROM palpated and the amount of pressure applied during testing was determined by the examiner. Although clearly there was room for bias in this manner of assessment, these were tools that are used in manual therapy and bodywork clinics through-out the world, and research has shown that although accuracy may be compromised in these techniques, precision rarely is compromised (Vincent-Smith and Gibbons, 1999; O'Haire and Gibbons, 1999). This can be translated as; if examiner A rates a joint as very tight (3 on the ROM chart), while examiners B–D rate a joint as tight (2 on the ROM chart), examiner A will go on to rate similarly restricted joints as "3" and the others will go on rating them as "2". There is nothing that can be done to enhance the accuracy of manual therapy methods outside of performing multiple tests (as utilized in this experimental design). Therefore patients must be assessed and their results recorded as they are in clinical practice. In absence of this approach, such research bears little relevance to the majority of practising manual therapists. Ultimately, in this research project, the mean score (critical value) may have been higher or lower, depending on the examiner, but the fact that the hamstring group scored a higher mean score than the control group would not have changed. This reliance on the high precision of intra-examiner reliability (Vincent-Smith and Gibbons, 1999) is what provided construct validity for this research paper (Hicks, 1999).

Recommendations for future research

Further research in this area is clearly warranted. A larger sample is required, and ideally a prospective trial should be conducted to assess whether subjects develop hamstring injuries subsequent to registering with lumbo-pelvic dysfunction on manual assessment. It could be argued that the high incidence of hamstring stain in soccer players may be more a feature of the sport rather than lumbo-pelvic dysfunction. However, this is not likely, as it is known that hamstring strain is the most common injury across the broadest range of sporting events—the Olympic games.

Conclusion

From this small sample, it was evident that the manual therapy assessment found greater dysfunction in players with a history of serious or recurrent hamstring strain; albeit statistically insignificant.

The dynamometer however, found greater dysfunction in those players who had been out of training for a prolonged period. Logically, a player who is becoming progressively deconditioned is more likely to register as "dysfunctional" on an active dynamometry test—in contrast to the passive manual assessment techniques.

Clearly, these two forms of dysfunction, passive and active, may be true of the same player and therefore the use both tools in assessment of lumbo-pelvic dysfunction associated with hamstring strain can be recommended. However, if manual therapy can be used preventatively to assess and correct dysfunction in muscle length tension relationships and arthrokinematics of the lumb-pelvic spine, it could be argued that intervention with an expensive and seldom available machine may not be necessary.

In conclusion, this research suggests that it may be effective for clubs and athletes to utilize manual therapy screening prophylactically to prevent injury; instead of in its traditional place as a purely reactive modality.

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