Low back pain and other overuse injuries in a group of Japanese triathletes

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Abstract

Objective—To document the incidence of low back pain and other overuse injuries in a group of triathletes, and to investigate any associations with various physical and triathlon related factors.

Methods—By means of a questionnaire, the physical characteristics, training habits, and the incidences of overuse injuries of 92 Japanese triathletes (70 males, 22 females) were documented. Student's *t* and χ^2 tests were used to determine the significance of any associations with injury incidence, as well as differences between subjects experiencing or not experiencing low back pain in the previous year.

Results—Low back pain was experienced by 32% of subjects in the previous year. The majority (54%) of low back pain episodes lasted under seven days, suggesting mainly soft tissue involvement, and 19% lasted over three months, suggesting involvement of the intervertebral discs. Weekly trunk flexor muscle training frequency was significantly greater ($P = 0.035$) for the low back pain subjects. Close to significant differences for average weekly cycling time, trunk flexor muscle training time, and low intensity aerobic training, as well as near significant associations for weight training and average weekly triathlon training load, were also found. No other factors were significantly associated with low back pain. Low back injuries accounted for 28% of all injuries. Only the knee was a more common single site of injury (33%).

Conclusions—The three most common injuries suffered by the triathletes were of the knee, back and shoulder. The low back pain suffered by many triathletes could be of a potentially serious nature. It is suggested that cycling is a major risk factor for low back pain in triathletes.

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Key terms: low back pain; triathlon; injury; cycling

Triathlon is an endurance sport involving swimming, cycling, and running. It has officially existed only for about 20 years, and during this time has developed very rapidly with regard to training strategies and cycling technology. Because of the short history of the sport, it has been very difficult to evaluate, or even predict, its long term physical effects (that is, sports related factors) on the participants. It is really only in the new or younger generation of triathletes, for many of whom triathlon was

their first sport, that these long term effects can be monitored and investigated more accurately. Data on triathlete injuries are sparse, and the most recent studies were performed some five years ago¹⁻⁷. This, along with the above mentioned rapid development of the sport – especially in recent years – indicates the strong need for further more comprehensive investigation into triathlon related injuries.

It has been argued that triathlon, as a multisport event, causes less overuse injuries than single sports, because of the more even distribution of loads over the body's musculoskeletal structures. Despite this, triathletes still suffer from a high degree of overuse injuries. These overuse injuries also account for as much as 85% of all injuries suffered.^{3,4} One commonly injured site is the low back.³⁻⁵

The main purposes of this study were to document the incidence of low back pain and other overuse injuries in a group of triathletes, and to investigate the associations between certain physical and triathlon related factors and the incidence of low back pain.

Methods

A pilot study was conducted to design a triathlon injury questionnaire to obtain data on the physical characteristics of triathletes (that is, age, height, weight, body mass index), their training habits (that is, weekly training times and distances, type of training performed and at what intensities, etc), as well as on their triathlon related injuries (their incidences and possible causes), in particular low back pain. In addition, test-retest reliability of the questionnaire was determined. It was found to be highly repeatable (Manninen J: Triathlon and lower back pain: a pilot study. Unpublished paper for physiotherapy masters programme. University of Jyväskylä, Finland, 1994). The questionnaire was then employed in this present study for obtaining the same type of data from the Japanese triathlete subjects.

Representatives of various triathlon clubs around Japan were contacted about the present study, and were told that it involved triathlon training methods and injuries. Once informed consent had been obtained from the representatives, questionnaires were mailed out. The numbers allotted to each club were based on estimates of club member numbers. The club representatives were asked to distribute the questionnaires to those club members willing to take part, and to then return both completed as well as unused questionnaires.

During March 1994, 185 questionnaires were mailed out to the representatives of 10

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The age distribution of the Japanese triathlete subjects.

selected triathlon clubs. Most were located in the Kinki, Chubu, and Kanto regions of Japan. Of these questionnaires, 109 were returned completed. The questionnaires returned by 17 subjects were excluded on the basis that they did not indicate that they were training all the three sports. Therefore, by definition, they were not triathletes. Due to the distribution method employed, the completion rate rather than actual response rate was calculated. The true completion rate for the triathlete subjects was 55% (92/168).

Statistical analyses included descriptive methods, Student's *t* tests, and χ^2 . The level of statistical significance for both the Student's *t* test and χ^2 analyses was set at $P = 0.05$. The Excel 4.0 and SPSS 6.0 computer software packages were employed to carry out these analyses.

Results

GENERAL

The physical characteristics of the triathletes are described in table 1. Only age did not differ significantly between male and female subjects. Most (63%) of the triathletes were aged 26 to 35 (figure), and most (96%) were in occupations involving sedentary or light activities (for example, business, office work, study, research, and medical). Only one subject was a professional triathlete. Six subjects smoked cigarettes regularly. Three of these subjects smoked one or less per day, while the other three smoked an average of 10 cigarettes per day.

The subjects had been training regularly for triathlon on average for 4.1 years (4.3 for males, 3.3 for females). The average weekly training times and distances of the triathletes are described in table 2. There were no significant gender differences except for weight training, in which females trained significantly less. Seventy three per cent of subjects performed weight training. Only 29% included circuit training in their overall training programme. Supplementary training (circuit and weight training combined), accounted for 12% of total training time. Swimming, biking, and running accounted for 29%, 38%, and 33% respectively, of total triathlon training time (that is, not including supplementary training). Further, 86% of subjects used triathlon "aerobars" (special handlebars) on their bicycles. Most of the training was performed at medium (41%) and low intensities (38%), the remainder being performed at high intensity.^a Over half (57%) trained for half and full distance events. The remainder (43%) trained for Olympic distance and sprint events. Before triathlon training, 27% of subjects participated in running, 12% in swimming, and only 4% in cycling. A regular stretching programme was followed by 94% of subjects. On average, this

Table 1 Physical characteristics of triathlete subjects. Values are mean (SD), [range]

	Male (n = 70)	Female (n = 22)	Total (n = 92)	P
Age (years)	31.6 (7.4) [19 to 52]	30.1 (7.3) [20 to 56]	31.3 (7.4) [19 to 56]	0.39
Height (m)	170.7 (6.5) [154 to 185]	158.0 (5.2) [143 to 165]	167.7 (8.2) [143 to 185]	< 0.01
Weight (kg)	63.8 (7.5) [46.0 to 85.0]	51.4 (4.6) [40.0 to 64.0]	61.0 (8.7) [40.0 to 85.0]	< 0.01
Body mass index (kg·m ⁻²)	21.8 (0.2) [17.3 to 30.1]	20.8 (0.3) [19.0 to 23.9]	21.6 (0.2) [17.3 to 30.1]	< 0.01

Table 2 Average weekly training times and distances of triathletes. Values are means (SD), [range]

	Male (n = 70)	Female (n = 22)	Total (n = 92)	P
Times (hours)				
Swim	3.6 (2.0) [0.3 to 10.0]	3.9 (1.9) [1.0 to 9.0]	3.7 (1.9) [0.3 to 10.0]	0.52
Bike	5.0 (2.7) [0.5 to 12.0]	4.8 (2.5) [1.0 to 10.0]	5.0 (2.6) [0.5 to 12.0]	0.73
Run	4.3 (2.0) [0.3 to 9.0]	4.6 (2.3) [1.0 to 13.0]	4.3 (2.0) [0.3 to 13.0]	0.58
Weights	1.4 (1.4) [0 to 5.0]	0.6 (1.1) [0 to 4.0]	1.2 (1.3) [0 to 5.0]	0.012 [P < 0.05]
Circuits	0.5 (1.0) [0 to 5.0]	0.5 (0.8) [0 to 2.5]	0.5 (1.0) [0 to 5.0]	0.98
Total	14.7 (6.4) [2.2 to 30.0]	14.4 (5.1) [5.0 to 24.5]	14.6 (6.1) [2.2 to 30.0]	0.87
Distances (km)				
Swim	6.4 (3.7) [0.3 to 20]	6.8 (3.3) [2 to 13]	6.5 (3.6) [3 to 20]	0.66
Bike	123.6 (67.5) [10 to 300]	99.8 (52.0) [30 to 200]	118.0 (64.7) [10 to 300]	0.09
Run	42.0 (24.3) [1 to 150]	43.0 (22.5) [5 to 120]	42.2 (23.8) [1 to 150]	0.87

^a Training intensity levels:

Low intensity – between the aerobic and anaerobic thresholds.

Medium intensity – at or below the aerobic threshold.

High intensity – at or above the anaerobic threshold.

Table 3 Low back pain incidence rates (%) of triathlete subjects

	Male (n = 70)		Female (n = 22)		Total (n = 92)	
	n	%	n	%	n	%
Lifetime	45	64	9	41	54	59
Yearly	23	33	6	27	29	32
Monthly	15	21	3	14	18	20
Point	9	13	2	9	11	12

was performed 6.8 times per week for 13.4 minutes each time.

LOW BACK PAIN

Thirty two per cent of subjects had experienced low back pain in the previous year. The incidence rates are given in table 3. There were no significant differences between males and females, although the males had a notably higher life time incidence rate ($P = 0.052$). The greatest incidence of low back pain occurred during the mid-season training phase (44%). A high proportion (23%) also occurred during the competition season. The average age that low back pain was first experienced was 23.7 years (23.8 for males, 23.0 for females). Initial low back pain episodes began for no particular reason, either suddenly or little by little, in 51% of subjects. Twenty two per cent stated that their initial pain episode had begun suddenly, but was due to some definite incident. The majority of pain episodes (54%) lasted under seven days. Twenty seven per cent lasted one week to three months, with the remainder (19%) lasting over three months. Pain had mainly been felt in the lower and upper back (58%), but 32% had, in addition to their low back pain, experienced lower limb symptoms in either one or both legs. The remainder had experienced lower limb symptoms in the absence of low back pain. Because of their low back pain, over half (56%) had stopped work or training for some time during the previous year. Four per cent had been unable to train at all for extended periods of time. Low back pain symptoms decreased in 45% of affected subjects over their period of triathlon training. Twenty nine per cent had not noted any overall changes.

Average weekly trunk flexor muscle training frequency was significantly greater in those subjects who had experienced low back pain in the previous year ($P = 0.035$). Other results also indicated close to significant differences (t tests) between the low back pain and non-low-back-pain subjects, or associations (χ^2 tests) with the incidence of low back pain in the previous 12 month period. These were: average weekly trunk flexor muscle training time ($P = 0.055$), average weekly cycling time ($P = 0.065$), proportion of low intensity aerobic training ($P = 0.09$) (t tests); performance of weight training ($P = 0.054$), and average weekly triathlon training load^a ($P = 0.095$) (χ^2 tests).^a The differences between low back pain and

^a Dichotomised groups based on average weekly triathlon training load.

Group 1: Swim ≥ 6 km, & bike ≥ 150 km, & ≥ 40 km per week ($n = 19$).

Group 2: All other subjects ($n = 73$).

Table 4 Injury rates of triathlete subjects

Number of injuries	Male (n = 70)		Female (n = 22)		Total (n = 92)	
	n	%	n	%	n	%
0	18	26	8	36	26	28
1	29	41	8	36	37	40
2	15	21	5	23	20	22
≥ 3	8	11	1	5	9	10

symptom-free subjects for gender, age, job activity level, flexibility, other training methods, and prior participation in other sports were not significant. Also, neither biking position, in terms of the degree of trunk flexion in a subject's usual cycling position, nor the use of triathlon "aerobars" was associated with the incidence of low back pain in the previous year, nor was the presence or number of lower limb injuries suffered during the previous year associated with the incidence of low back pain in that year. Seventy four per cent of the low back pain subjects associated pain with cycling, 45% with weight training, and 43% with running. The least likely association stated was for circuit training (19%).

OTHER INJURIES

Seventy two per cent of subjects had sustained at least one musculoskeletal injury related to triathlon in the previous year. Of this group, 30% had sustained two injuries, and 14% had sustained three or more injuries (see table 4). Most injuries involved the lower limb (61%), of which the knee was the most common site of injury (54% of all lower limb injuries). Running was the most common activity stated as a cause of lower limb injury. Specific reasons included overtraining, faulty running technique, a hard running surface, and inadequate stretching. Only 8% of injuries were of the upper limb, all involving the shoulder. Swimming related factors were stated as the causes of all shoulder injuries. They included poor swimming technique, inadequate stretching, and inadequate warm up. An injury involving the spinal region had been sustained by 32% of subjects (lower back injuries 28%, neck/cervical region 4%). Only the knee was a more common single site of injury (33%). Table 5 classifies the injuries according to anatomical region.

Discussion

The subjects in this study comprised a totally homogeneous group by race, that is, they were

Table 5 Anatomical distribution (%) of injuries (n = 105) in triathlete subjects (n = 66)

Anatomical site of injury	Frequency	
	n	%
Knee	35	33.3
Low back	29	27.6
Shoulder	9	8.6
Ankle	8	7.6
Calf	5	4.8
Plantar arch	4	3.8
Neck/cervical region	4	3.8
Tibia	4	3.8
Achilles tendon	3	2.9
Thigh	2	1.9
Heel	1	1
1st Metatarsophalangeal joint	1	1
Total	105	100

all Japanese. In comparison with other studies involving triathlete subjects,^{3,5,6} the subjects were generally younger (by approximately five to seven years), although their age was similar to that of the subjects in the study by Ireland and Micheli.² Also, they were generally lighter and shorter. The majority of triathletes in this study were distributed in the 26–30 and 31–35 year age groups. The subjects trained somewhat less than those in the previously mentioned studies, but this was most probably due to the inclusion of a wider range of triathletes in terms of skill, training, and competition level. Almost all subjects followed a regular stretching programme, compared to the figure of 65% reported by Ireland and Micheli. Interestingly, very few subjects had occupations related to sport or triathlon, the majority being primarily involved in employment of a non-physical nature.

The methodological approach employed did not allow generalisation about the entire population of Japanese triathletes. However, the results were perhaps more descriptive of general triathlon populations than those in previous studies, as the subjects were not selected through participation in a particular competition (for example, full distance triathlon), but on the basis of varying geographical location. The incidence rates for all injuries may have been somewhat exaggerated due to a possible non-participation by uninjured triathletes. However, we were aware of this problem from the outset. We attempted to minimise this possible selection bias by promoting the study as looking at both triathlon training methods and triathlon overuse injuries generally, rather than emphasising the latter. Further, the questionnaires were completed during the mid-season training season, as opposed to after competitions. This could be expected to improve the reliability and generalisability of the results for two reasons. First, their training would have been of a more typical nature than that done during the competition season. Second, non-typical phenomena, such as normal post-race recovery "pain" and fatigue, which could have been falsely interpreted as an injury, would have been excluded.

LOW BACK PAIN

The subjects in this study could be considered to be much fitter and stronger than the general population, that is, all other persons not involved in regular and very physically demanding athletic activities. The overwhelming majority did not smoke, were not overweight, and were most probably very determined and goal oriented people, as reflected by their involvement in the sport. Despite the relative lack of common low back pain risk factors, the incidence of low back pain of the subjects was not less than that reported for the general population,^{9–10} as might be expected. While the point incidence (12%) was at the lower limit of the general population values, the lifetime incidence rate (59%) was in the middle range. This is interesting as the average age of the triathlete subjects was 31.3 years, with the age distribution of subjects in epidemiological studies involving

the general population ranging mainly from 30 to 60 years.¹⁰ In previous studies on the general population, either no gender differences had been found, or the incidence had been greater for females, especially when work practices were taken into account.¹¹ In contrast, the males in this study experienced a greater incidence of low back pain than the females. The difference was not statistically significant, but was in fact very close ($P = 0.052$) to the set level of significance. This gender difference may be related to differences in training methods or volumes. For example, differences for cycling and weight training between males and females were either statistically significant or showed very strong trends.

Lumbar spine injuries account, on average, for approximately 5–10% of all athletic injuries, including both overuse and traumatic injuries.^{12,13} Sports such as gymnastics show the highest low back injury rates.^{14,15} In triathlon, low back injuries account for 4–17% of all the overuse injuries sustained,^{1–4,7} which is comparable to the figures for other sports. In this study, low back complaints accounted for almost 28% of all overuse injuries suffered in the previous year. O'Toole *et al*⁵ reported that an astonishing 72% of subjects had complained of low back pain or sciatica in the previous year. There are very few data on the incidence rates of low back pain for cyclists, but Mellion¹⁶ stated that up to 60% of cyclists have suffered from it at some time. This closely matches the life time low back pain incidence rate (59%) of the triathlete subjects in this study. These figures show that low back pain in triathletes is as prevalent as in other sports, and if traumatic low back injuries are excluded, then the prevalence would be even higher.

According to Mooney's classification of low back pain based on the potential for spontaneous recovery,¹⁷ the majority of low back pain in this group of triathletes could be attributed to soft tissue or myofascial structure injuries. Involvement of the zygapophyseal joints was also likely, though a portion of suspected zygapophyseal joint problems could also represent a continuance of acute soft tissue injuries due to secondary reflex activity, that is, the pain-spasm cycle. Of concern was that almost 20% of all the pain episodes had lasted over three months. According to the same classification, a more serious pathology or problem may have existed, namely a possible injury of the intervertebral disc. While relatively frequent soft tissue injuries of short duration would be expected for triathletes involved in regular, often very physically demanding, training, the proportion of long duration pain episodes was quite high, and was a clear danger sign of potential future and possibly severe long term disability.

General risk factors for low back pain have been given for the general population.¹⁰ It would be expected that many of these risk factors, especially the physical risk indicators such as poor trunk muscle strength and endurance, cardiovascular fitness and flexibility, as well as smoking, would be minimal in a group of trained athletes. This study revealed that

increased trunk flexor muscle training frequency, that is, the number of times they were trained weekly on average, was significantly associated with an increased incidence of low back pain in the previous year. Possibly the training exercises for the trunk flexors were performed incorrectly. This may have resulted in inappropriate stresses on the lumbar spine. Also, it is possible that subjects began to train their trunk flexor muscles more frequently only after they had experienced low back pain. This may have been done in an attempt to rehabilitate themselves in the belief that greater abdominal muscle training may decrease their symptoms. However, this may have actually contributed further to a deterioration or prolongation of the acute phase symptoms. Another possibility is the presence of trunk muscle imbalances. Low back pain subjects have been seen to be flexor overpowered,¹⁸ ratios of 1.0 to 0.8 (trunk extensors to flexors) having been reported.^{19, 20} Normal values are in the order of 1.3.¹⁹ Perhaps the triathlete subjects with low back pain in this study were flexor overpowered because they exercised their abdominal muscles more than their back extensor muscles. However, it is not clear whether an imbalance is a causal factor or a result of low back pain. While it is very difficult to draw definite conclusions about the causes, clearly how the muscles are trained is just as important as how often and how much.

Other possible causes of low back pain in athletes have been suggested previously in the literature.^{1, 4, 5, 21, 22} Excessive or repetitive loading of the spine is a major cause of back injury in endurance athletes.²³ Repetitive loading results in a weakening of the viscoelastic passive elements of the spinal structures. The loss of ability to protect these weakened passive elements makes the spine susceptible to injury.²² With an inability to dissipate forces at one joint, there is a resultant overload at the next joint as forces ascend upwards towards the skull.^{24, 25} Should there be some kind of lower limb disorder, then abnormal forces could be incident on the lumbar spine.⁵ It has been suggested that malalignment in the foot leads to other foot problems, to knee problems, and subsequently to lumbar spine problems.²¹ This has been seen in triathlete injury patterns, with back pain occurring frequently in combination with lower limb injuries.^{1, 5}

While running may cause most overuse injuries in triathletes,¹⁻³ this does not necessarily mean it is the primary cause of low back pain. Cycling, may in fact be the key component predisposing to low back pain, even though it is responsible for only 12–29% of overuse injuries in triathletes.^{1, 2, 4} Migliorini⁴ found that the change from the “off” load of cycling, to the “on” load of running, as weight bearing begins, was the cause of most complaints. Muscle activity changes from being mostly concentric during cycling to include also eccentric muscle work during running. It has been postulated that a time lag exists after cycling, before neuromuscular and elastic efficiency – which is indispensable for proper running technique – can reach its optimal level.

The triathlete is perhaps more susceptible to lower back injury during the initial stages of the run, when this transition is occurring. Migliorini suggested that this transition period lengthens with an increase in the length of the biking phase. In our study, those experiencing low back pain in the previous 12 months reported a greater average weekly cycling time, though this was not statistically significant ($P = 0.065$). This result provides some support to Migliorini's suggestion. In order to maintain an aerodynamic cycling position, as well as an appropriate degree of hip flexion for optimal force generation during the pedalling cycle, the lumbar spine is often held in a relatively flexed position. Sitting, especially in a flexed position and for long periods, has been shown to increase intradisc pressure, thereby predisposing to low back pain.¹⁰ Thus it is very important to examine cycling position and its association with the incidence of low back pain. The present study did that, although very generally, with no significant associations being found. It would have been beyond the scope of this study to examine the relation in greater detail. However, future research should be carried out to look at how (inappropriate) cycling position may cause, or contribute to, low back pain. Further, the possible detrimental effects of vibration as a risk factor cannot be ruled out. So, while running may have been the final factor producing marked symptoms or injury, it is quite possible that the initial cause of the low back pain originated from cycling. This is further supported by the majority of subjects themselves implicating cycling as the main cause of their low back pain.

There was some indication ($P = 0.095$) that average weekly triathlon training load was associated with low back pain incidence. It is reasonable to assume that those training more place greater overall cumulative physical stress on their bodies than those who train less. This could indicate that even among top level triathletes there is an upper “safe training limit or zone” beyond which an increase in training load would produce a non-proportional and greater increase in the risk of injury. Of course, this theoretical upper limit would vary between individuals, but perhaps certain generalisations can be made.

OTHER INJURIES

In our study, the incidence of musculoskeletal injuries related to triathlon was very similar to those reported previously,^{1, 2, 4} with approximately 60% of triathletes having suffered at least one soft tissue overuse injury in the previous year. Lower limb injuries accounted for 61% of all injuries in this study, compared to the figure of 85% reported by Ireland and Micheli.² Also, the anatomical sites of injury were closely matched. In all studies, the knee was the single most common site of injury (30–50%). Injuries of the lower back (28%) were the second most common in this study, though in other studies they were the third most common site (4–17%) after the shoulder,² foot, or ankle.³ However, in the study by Collins *et al*,¹ the back was the most commonly injured

site. O'Toole *et al*⁵ revealed that low back injuries occurred frequently in combination with lower limb injuries, although there were no statistically significant associations in our study. The shoulder is the most common site of upper limb injuries, but the incidence has been quite varied. In this study, injuries to the shoulder were the third most common, and comprised all upper limb injuries.

CONCLUSION

Low back pain is a common problem suffered by triathletes. Despite the relative absence of general risk factors for low back pain, triathletes still suffer from it as much as the general population or other athletes such as cyclists. While most pain episodes are of short duration and involve the soft tissues, a relatively high proportion are of longer duration. These most probably implicate involvement or injury of the intervertebral disc. This clearly indicates that triathletes are at risk of suffering low back pain of a serious nature. Despite the fact that only one statistically significant difference was found between low back pain and non-low-back-pain subjects, there were several other strong indications for possible associations of certain training related factors with the incidence of low back pain. The three most common sites of injury in the present study were of the knee, low back, and shoulder. While most knee injuries in triathlon are caused by running, and the majority of shoulder injuries by swimming, there is no one clear cause of injury to the lower back, though cycling is suggested as a major contributing factor. The sports related factors likely to increase the risk of low back pain must be more clearly identified, and their effects minimised. The results of this study give direction for the design of controlled interventional studies, so that these factors and their associations with low back pain in triathletes can be investigated more accurately.

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- Collins K, Wagner M, Peterson K, Storey M. Overuse injuries in triathletes: a study of the 1986 Seafair Triathlon. *Am J Sports Med* 1989;17:675-80.
- Ireland M, Micheli L. Triathletes: biographic data, training, and injury patterns. *Ann Sports Med* 1987;3:117-120.
- Massimino F, Armstrong M, O'Toole M, Hiller W, Laird R. Common triathlon injuries: special considerations for multisport training. *Ann Sports Med* 1988;4:82-6.
- Migliorini S. An epidemiological study of overuse injuries in Italian national triathletes in the period 1987-1990. *J Sports Traumatol Rel Res* 1991;13:197-206.
- O'Toole M, Hiller D, Smith R, Sisk T. Overuse injuries in ultraendurance triathletes. *Am J Sports Med* 1989;17:514-8.
- O'Toole M, Massimino M, Hiller D, Laird R. Medical considerations in triathletes: the 1984 Hawaiian Ironman Triathlon. *Ann Sports Med* 1987;3:121-3.
- Williams M, Hawley J, Black R, Freke M, Simms K. Injuries amongst competitive triathletes. *NZ J Sports Med* 1988;16:2-6.
- Heliövaara M, Sievers K, Impivaara O, Maatela J, Knekt P, Mäkelä M, Aromaa A. Descriptive epidemiology and public health aspects of low back pain. *Ann Med* 1989;21:327-33.
- Kelsey J, White A. Epidemiology and the impact of low back pain. *Spine* 1980;5:133-42.
- Pope M. Risk indicators in low back pain. *Ann Med* 1989;21:387-92.
- Magora A. Investigation of the relation between low back pain and occupation. II. Work history. *Ind Med Surg* 1970;39:504-10.
- Harvey J, Tanner S. Low back pain in young athletes. A practical approach. *NZ J Sports Med* 1991;12:394-406.
- Lachmann S. *Soft tissue injuries in sport*. London: Blackwell Scientific Publications, 1988:3.
- Goldstein J, Berger P, Windler G, Jackson D. Spine injuries in gymnasts and swimmers: an epidemiological investigation. *Am J Sports Med* 1991;19:463-8.
- Meeusen R, Borms J. Gymnastic injuries. *Sports Med* 1992;13:337-56.
- Mellion M. Common cycling injuries. *Sports Med* 1991;11:52-70.
- Mooney V. The classification of low back pain. *Ann Med* 1989;21:321-5.
- Pope M, Bevins T, Wilder D, Frymoyer J. The relationship between anthropometric, postural, muscular, and mobility characteristics of males ages 18-55. *Spine* 1985;10:644-8.
- Beenbon D, Morrissey M. A review of the literature related to trunk muscle performance. *Spine* 1988;13:655-60.
- McNeill T, Warwick D, Anderson G, Schultz A. Trunk strengths in attempted flexion, extension and lateral bending in healthy subjects and patients with low-back disorders. *Spine* 1980;5:529-38.
- Micheli L. Lower extremity overuse injuries. *Acta Med Scand (suppl)* 1986;711:171-7.
- Parniapor M, Nordin M, Kahanovitz N, Frankel V. 1988 Volvo award in biomechanics. The triaxial coupling of torque generation of trunk muscles during isometric exertions and the effect of fatiguing isoinertial movements on the motor output and movement patterns. *Spine* 1988;13:982-92.
- Mahlamäki S. Low back symptoms and signs in young cross-country skiers: a cross-sectional and follow-up study on the low back symptoms and signs, as well as related factors, of 10-16 year skiers and controls living in the North-Savo area. Kuopio, Finland: Kuopio University, 1987:23.
- Voloshin A, Wosk J. An in vivo study of low back pain and shock absorption in the human locomotor system. *J Biomech* 1982;15:21-7.
- Voloshin A, Wosk J, Brull M. Force transmission through the human locomotor system. *J Biomech Eng* 1981;103:48-50.