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Effect of different sports on young athlete's posture swimmers and cyclists

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Abstract

Background & Study Aim: In each sports discipline morphological characteristics, elements of technical, tactical, and psychological preparation can be distinguished whose high level may affect sports results. The aim of this study is knowledge about the express diagnostic program and the possibility of detecting changes in musculoskeletal posture in young athletes practicing various sports disciplines.

Material & Methods: The participants were 38 athletes from sports clubs in Riga, Latvia, swimmers (n = 19), and cyclists (n = 19) aged 14-15 years old with experience in National competitions. Body posture was assessed once before the training for visual diagnostics and muscular functional testing. A diagnostic program was developed from these methods, which included measuring the changes of 8 sagittal points from the vertical plane and functional testing of 8 muscle groups. The analyses were conducted using IBM SPSS version 26. The Shapiro-Wilk test, an independent t-test and the Mann-Whitney U test were used to analyse the data.

Results: The results showed that both groups (n = 38); standing posture was falling forward. There were significant differences between the two groups. Cyclists demonstrated significant results than swimmers for the following posture indicators - External Ear Opening (EEO), Radial Point (RP), Highest Point of the Iliac Crest (HPIC), M. Pectoralis Major Upper part (MPMU), Outer Points of the Palm (OPP), Acromion (ACR), Trochanter (Tro), Upper End of Fibula Bone (UEFB), M. Rectus Abdominis (MRA) and Blade Fixators (BF). There were significant results for swimmers in M. Quadriceps Femoris (MQF) and M. Gluteus Medium (MGM) at the 5% level. There was not a significant difference between the two groups in Hamstring Muscles (HM) and for M. Iliopsoas (MI).

Conclusions: It can be concluded that each sport leads to postural changes in athletes due to specific functional muscle changes, as the results highlighted changes in both groups. Early postural changes in young athletes can be identified by applying express diagnostics. Early detection should lead to the prevention of injury.

Keywords: body posture • innovative agonology • training loads

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Body posture – the formation of the body and the position of the different elements in relation to each other in an upright position. [45].

Athlete – *noun* 1. someone who has the abilities necessary for participating in physical exercise, especially in competitive games and races **2.** a competitor in track or field events [45].

Player – ***noun*** someone taking part in a sport or game [45].

Performance – ***noun*** the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [45].

Racket sport – ***noun*** any of various sports that use a racket and ball or shuttlecock, e.g. Tennis, badminton or squash [45].

Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (...) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '***workload volume***'. (...) Due to the fact that the heart rate (HR) is commonly accepted as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of ***training load*** defined as the amount of workload. It is useful in analyses with a high level of generality. (...) In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [46, p. 238].

Training session – ***noun*** a period of time during which an athlete trains, either alone, with a trainer or with their team [46].

INTRODUCTION

The high occurrence of postural disorders in some sports among adolescents has questioned the influence of sports on the athletes' postures. Excessive training in some sports makes deviates from correct posture [1]. It is assumed that the specific technical (in motoric sense) requirements and training loads in some sports during the performance and long repetition of them affected the postural disorders. Some sports, such as dancing, rhythmic gymnastics, and figure skating, are described by the spinal column's extreme range of motion [2]. Athletes who practice these sports have abnormalities in the spine and a high risk of injury to this part of the body. There is no single sport nowadays where athletes do not have a spinal column disorder, whereas the level and type of disorder depend on the nature of the sport and, above all, from the training load.

Studies have shown that athletes are more prone than non-athletes, suffering from postural deviations. Deviations of the spine develop progresses for athletes in two ways: left and right (at the frontal level). Scoliosis in racket sports and javelin and hammer throwers and anterior /posterior changes (on the sagittal level) such as lordosis in horse riders, kyphosis in cyclists, boxers, swimmers, wrestlers, and weightlifters [3]. The research Rajabi et al. [4] on cyclists showed that the amount of kyphosis in cyclists is significantly higher than in non-cyclists. In a study Rajabi et al. [3], the researcher compared back kyphosis in two wrestling groups (freestyle and Greco-Roman) – the freestyle wrestlers had the highest amount of kyphosis, and Greco-Roman wrestlers had the least amount of kyphosis. Another study [5] showed that volleyball players had slumped shoulders and kyphosis-lordosis posture, and handball players had drooping shoulders, flat soles, crooked thumbs, and patella displacement. A study [6] reported the number of forward bends and rounded shoulders in top swimmers.

The research [7] found that in adolescents participating in vigorous sports, such as footballers, hockey players, swimmers, and wrestlers, which exceed 400 hours per year of intensive training with an undeveloped spinal column, there is an increased deflection in the sagittal plane, the thoracic hyper kyphosis, and lumbar hyperlordosis. A study [8] researched the degree of kyphosis in cyclists and their position. The results have shown that the degree of kyphosis has been affected by the years of training. A professional cyclist has more degree of kyphosis than an amateur cyclist. Reduced range of motion, decreased strength, and performance concerning velocity and accuracy can manifest in shoulder pathology [9]. A study conducted on 372 players (athletes) in different sports, such as basketball, badminton, gymnastics, swimming, squash, tennis, table tennis, and volleyball, shows that (n = 163) had shoulder problems such as pain, weakness, and decreased range of motion [10].

Swimming as a cyclical sport includes repeating many of the same movements. Its repetitive nature could represent one of the main factors in the occurrence of certain postural disorders of the spinal column, the specific nature of the movements being performed, and the environment in which the movements are made. Kyphosis and lordosis have been determined among swimmers in the studies. Some researchers [11] have defined a thoracic hyper kyphosis among 70% of the athletes. Reduced values of thoracic kyphosis were not determined among swimmers, while lumbar kyphosis was noticed in 27%. The muscles most responsible for propulsion in swimming are the *pectoralis* (colloquially 'pecs', 'pectoral muscle', or 'chest muscle'), *latissimus dorsi* ('broadest [muscle] of the back'), *biceps brachii* ('two-headed muscle of the arm'), *rectus abdominis* ('abdominal muscle' or simply the 'abs'), and *gluteus maximus* (is the main extensor muscle of the hip in humans) [12].

Depending on the type of activity, each athlete is prone to a specific type of deformity, even the spine's shape. Different sports are affected explicitly according to their activity. A person's ability to perform activities in a sport depends on his physical condition, so the physical condition is the basis of all human movements [5, 6]. Based on the above, this research aims to determine if an express diagnostic program could detect postural muscular-skeletal changes in young athletes, swimmers, and cyclists and if there are any posture differences between swimmers and cyclists.

The aim of this study is knowledge about the express diagnostic program and the possibility of detecting changes in musculoskeletal posture in young athletes practicing various sports disciplines.

MATERIAL AND METHODS

Participants

The participants were 38 male athletes from sports clubs in Riga, Latvia, swimmers (n = 19), and cyclists (n = 19) aged 14-15 years old with experience in national competitions. They had six training sessions per week, every session was 90 minutes.

The Ethics Committee of the Latvian Academy of Sport Education in Riga approved the study protocol, and all procedures followed the ethical standards of the Declaration of Helsinki.

Procedure

Body posture was assessed according to [13] for visual diagnostics and [14, 15] for muscular functional testing. A diagnostic program was developed from these methods [16], which included measuring the changes of 8 sagittal points from the vertical plane and functional testing of 7 muscle groups. Body posture was assessed one time before the training. The assessments were performed in March 2022.

Express diagnostics of posture statics.

The following points (8 points) were marked on the athlete's body: external ear opening (EEO), acromion (Acr), radial point (RP), outer points of the palm (OPP), highest point of the iliac crest (HPIC), trochanter (Tro), upper end of fibula bone (UEFB), and outer ankle (OA). The athletes stood relaxed close to a vertical wall. The distance from the marked point to the vertical wall on the right and left sides was measured simultaneously with the meter stick from both sides. The middle distance was counted. The distance from the ankle to the wall was considered '0', so this measurement was subtracted from the numbers in centimetres (cm) from all mentioned points.

Muscle functional testing

According to Kendall, the central body and leg muscles involved in posture forming were tested to state the postural tone and phasic contraction muscle functional condition [14]. Muscles were tested at rest condition to determine muscle shortening and weakening. Seven muscle groups were examined: the phasic muscles, such as blade fixators (BF), muscle rectus abdominis (MRA), muscle gluteus medium (MGM), and the postural muscles, such as muscle pectoralis major upper part (MPMU), muscle iliopsoas (MI), muscle quadriceps femoris (MQF), hamstring muscles (HM), and the functional condition of the postural muscles was assessed according to Janda [15].

Statistical analysis

The estimation of the results is based on the following indicators: frequency (N, n); mode (see glossary); mean (M); median (Me); minimum (Min); Maximum (Max); standard deviation (SD or ±); standard error (SE) as well as the following statistical indicators: distribution, F-Snedecor statistics, result of the analysis of variance (*F*); degrees of freedom (*df*); significance level, probability (*p*).

The normality of data distribution and sphericity were estimated using the Shapiro–Wilk statistics and Levene's test for equality of variances. To compare means (M) between 2 groups, if the normality of data distribution were confirmed and Levene's test results were not significant, then using an independent samples t-test. If the normality of data distribution was confirmed, and Levene's test results were significant, the Welch test was conducted (due to unequal variances). The Mann-Whitney U test was used when normality assumptions were not met. The level of significance was set at $p < 0.05$. The analyses were conducted using IBM SPSS version 26.

RESULTS

The body deviation forward, so-called 'body falling', was observed in both groups in acromion (Acr), for the sswimmers mean was M = 11.62 ±0.23 and for the cyclists M = 11.4 ±0.10. Both swimmers and cyclists had a round back and a slight forward rotation of the pelvis. As in highest point of the iliac crest (HPIC) for the swimmers M = 6.83 ±0.23, and the cyclists M = 9.47 ±0.18. The outer points of the palm (OPP) in cyclists were more considerable than for the swimmers: M = 9.41 ± 0.22, and M = 6.43 ±0.37 (Table 1).

To compare the results of posture indicators between the swimmers (n = 19) and the cyclists (n = 19), the Independent t-test showed that there were significant differences between 2 groups (Table 2).

Cyclists demonstrated significant results than swimmers for EEO (external ear opening) as $t(36) = 38.16$, p = 0.001, RP (radial point) $t(36) = 35.10$, p = 0.001, HPIC (highest point of the iliac crest) $t(36) = 38.30$, p = 0.001, MPMU

Innovative agonology – is an applied science dedicated to promotion, prevention and therapy related to all dimensions of health and regarding the optimization of activities that increase the ability to survive from micro to macro scales [40, p. 274].

INNOAGON – acronym 'innovative agonology'[41].

Mode – in statistics, the mode is the value that appears most often in a set of data values. If X is a discrete random variable, the mode is the value x at which the probability mass function takes its maximum value (i.e, x =argmaxxi P(X = xi)). In other words, it is the value that is most likely to be sampled. Like the statistical mean and median, the mode is a way of expressing, in a (usually) single number, important information about a random variable or a population. The numerical value of the mode is the same as that of the mean and median in a normal distribution, and it may be very different in highly skewed distributions [47].

Table 1. Descriptive statistics for swimmers (n = 19) and cyclists (n = 19).

Indicator	Group	Mode	Median	Mean	SD	Min	Max
EEO	cyclists	12.10	12.20	12.18	0.12	12.00	12.40
	swimmers	10.10	10.10	10.10	0.20	9.70	10.50
ACR	cyclists	11.50	11.40	11.43	0.10	11.30	11.60
	swimmers	11.60	11.60	11.62	0.14	11.40	11.90
RP	cyclists	4.80	4.90	4.93	0.17	4.70	5.20
	swimmers	2.80	2.70	2.67	0.22	2.30	3.10
OPP	cyclists	9.30	9.40	9.41	0.22	9.10	9.80
	swimmers	6.00	6.40	6.43	0.37	5.80	7.20
HPIC	cyclists	9.40	9.50	9.47	0.18	9.20	9.80
	swimmers	6.60	6.80	6.83	0.23	6.40	7.20
Tro	cyclists	5.70	5.70	5.65	0.10	5.50	5.80
	swimmers	5.10	5.20	5.17	0.14	5.00	5.40
UEFB	cyclists	2.80	2.80	2.75	0.10	2.60	2.90
	swimmers	2.20	2.30	2.31	0.13	2.10	2.50
OA	cyclists	0	0	0	0	0	0
	swimmers	0	0	0	0	0	0
MPMU	cyclists	26.00	25.00	24.67	3.15	20.60	32.00
	swimmers	38.50	37.00	37.77	3.01	33.50	43.00
HM	cyclists	52.00	54.80	54.48	3.79	47.00	61.00
	swimmers	53.00	57.00	56.25	3.57	47.50	62.00
MQF	cyclists	55.80	55.80	54.36	4.69	46.00	61.50
	swimmers	59.00	61.80	61.35	3.30	54.00	66.50
MI	cyclists	81.00	85.20	84.86	3.84	79.00	91.50
	swimmers	89.00	86.80	86.35	3.73	81.20	93.00
BF	cyclists	51.50	60.50	59.60	4.02	51.50	66.00
	swimmers	89.00	89.00	89.28	3.10	84.80	94.50
MRA	cyclists	49.50	46.90	45.79	5.20	34.00	52.00
	swimmers	41.00	41.00	39.90	3.52	33.00	45.00
MGM	cyclists	22.00	21.70	21.78	4.49	16.30	30.00
	swimmers	61.00	61.00	61.28	2.56	55.00	66.00

SD standard deviation; **EEO** external ear opening; **Acr** acromion; **RP** radial point; **OPP** outer points of the palm; **HPIC** highest point of the iliac crest; **Tro** trochanter; **UEFB** upper end of fibula bone; **OA** outer ankle; **BF** blade fixators; **MRA** muscle rectus abdominis; **MGM** muscle gluteus medium; **MPMU** muscle pectoralis major upper part; **MI** muscle iliopsoas; **MQF** muscle quadriceps femoris; **HM** hamstring muscles

Table 2. Differences in the posture indicators between swimmers (n = 19) and cyclists (n = 19).

Indicator	Levene's test for equality of variances		95% CI for mean difference							
	F	Sig	M diff	SE diff	lower	upper	t	u	df	p
EEO	2.41	0.12	2.07	0.05	1.96	2.18	38.16		36	**0.001***
ACR**	1.21	0.27			–0.30	–0.10		54.50		**0.001***
RP	1.58	0.21	2.26	0.06	2.13	2.39	35.10		36	**0.001***
OPP	4.87	**0.03*****	2.97	0.10	2.77	3.18	29.36		29.55	**0.001***
HPIC	1.42	0.24	2.63	0.06	2.49	2.77	38.30		36	**0.001***
Tro**	1.53	0.22			0.40	0.60		361.0		**0.001***
UEFB**	0.61	0.43			0.40	0.50		361.0		**0.001***
MPMU	0.002	0.96	–13.10	1.00	–15.13	–11.07	–13.10		36	**0.001***
HM	0.19	0.66	–1.76	1.19	–4.19	0.65	–1.48		36	0.14
MQF	4.66	**0.038*****	–6.98	1.31	–9.66	–4.31	–5.30		32.33	**0.001***
MI	1.90	0.99	–1.48	1.23	–3.98	1.00	–1.21		36	0.23
BF	0.75	0.39	–29.68	1.16	–32.05	–27.32	–25.46		36	**0.001***
MRA**	1.78	0.18			4.00	9.00		299.0		**0.001***
MGM	8.24	**0.007*****	–39.50	1.18	–41.92	–37.09	–33.29		28.61	**0.001***

CI confidence interval; **F** F distribution; Levene's test uses this statistic to assess whether the variances of different groups are equal. **Sig** significance (p<0.05); **SE diff** standard error of the mean difference; ***t*** *t statistics;* ***u*** Mann-Whitney u test; **df** degrees of freedom; **p** p-value; *Significant (p<0.05), **non-parametric tests; ***Levene's test is significant (p<0.05); **diff** difference

(m. pectoralis major upper part) *t* (36) = −13.10, p= 0.001, BF (blade fixators) *t* (36) = −25.46, p = 0.001. The independent t-test showed no significant difference between swimmers and cyclists in HM (hamstring muscles) as *t*(36) = −1.48, p = 0.14, and for MI (m. iliopsoas) *t*(36) = −1.21, p = 0.23. The Welch's test indicated significant results for cyclists in OPP (outer points of the palm) as *t*(29.36) = 2 9.55, p = 0.001. On the other hand, the Welch's test indicated significant results for swimmers than cyclists in MQF (m. quadriceps femoris) as *t* (32.33) = −5.30, p = 0.001, and for MGM (m. gluteus medium) *t*(28.61) = −33.29, p = 0.001. According to the Mann-Whitney U test, the cyclists had significant results for ACR (acromion) as U = 54.50, p = 0.001), Tro (trochanter) U = 361.0, p = 0.001, UEFB (upper end of fibula bone) U = 361.0, p = 0.001, and MRA (m. rectus abdominis) U =2 99.0, p = 0.001, indicate that the difference is significant at the 5% level.

DISCUSSION

This research indicates that sports event specifics affect posture and muscle imbalances. Analysing muscles according to their tone they can be divided into two groups: posturally and physically contracting muscles. The postural muscles that form posture have relatively high tone. However, if these muscles are overloaded, the tone pathologically increases, and the muscle cannot contract nor relax effectively enough to allow the antagonist to work. Physically contracting muscles that provide movements have lower tone than postural muscles. If they are overloaded, their effective activity decreases. They lengthen and cannot be acquired effectively [17]. Balanced work of the phasic and postural muscles is one of the preconditions for forming a correct posture. The muscles are in definite strength relations, providing typical or accurate stereotypes; thus, every movement is executed with optimal strength.

An racket athlete's profile (deviation from the vertical line in the sagittal plane) explains that an athlete's muscle imbalance is caused by the centre of gravity being further forward than is considered neutral [13]. Regarding postural muscles, the tone pathologically increases, and the muscle cannot contract nor relax enough to allow the antagonist to work. Athletes in all groups have short pelvic and hamstring muscles. If the leg and pelvic muscles are shorter, the lordosis of the lower back increases, the spine amortization function decreases, and there is equal load division.

The upper cross syndrome is characteristic of athletes of cyclic sports, e.g., swimming and rowing. Loading of the sport on the shoulder girdle shows the spine hyper-kyphosis of the chest part and the shortening of the small chest and upper trapezius muscles [16]. The lower cross syndrome is characteristic of athletes of sports requiring complicated coordination (e.g., Ice-hockey and basketball) at high load on lower extremities: "body falling" forward, hyper-lordosis of the chest-pelvis area, and the shortening of the pelvic muscles at weakened major hip muscles and m. rectus abdominis [18].

In our research, scoliotic bad posture was determined in all swimmers, so we can conclude that a specific discipline does not cause scoliosis but that the occurrence of this postural disorder depends on other factors. A researcher Tanchev et al. [19] considered three main factors significantly influencing the onset of scoliosis. They are general joint mobility, slow growth, development (we will comment on the validity of using this term in the area of human motor skills later in the 'discussion'), and maturation due to physical, dietary, and physiological stress and the constant asymmetric load on the spinal column. Even though the load in all joints in an aquatic environment is significantly smaller, many repeated movements due to the cyclical nature of swimming cause a significant load on all the joints and, thus, the spinal column itself. Considering the significant number of training sessions during one microcycle, it is clear that for swimmers who are still maturing, this represents a significant burden that could negatively influence the formation of physiological curvatures. Puberty and the pre-adolescent period for ages 10 to 18 are considered a period of rapid growth of all the spinal column segments [20]. During this period, many children participate in the intense training process and begin their active swimming career, which leads to the possibility of forming a postural disorder of the spinal column.

In addition, specific disciplines, such as the backstroke, require great flexibility of the shoulder belt so that the arm's stroke can lead to the most optimal position and allow the unhindered passage of the second arm in the return phase. A study [21] has shown that young females with loose joints can be more prone to idiopathic scoliosis. Even though swimming is a cyclical sport, poor technique, or the tremendous strain on the muscles of the dominant arm to achieve a more effective stroke in the propulsion phase can lead to asymmetric load on the musculature. With increased speed and the body's surface, increased resistance in the water is applied by applying various drag forces or through poor technique or greater strength in the dominant arm; multiple types of resistance are created, which can cause muscular disbalance after a long time. The study [22] determined that within 16% of the participants with functionally mild scoliosis, the lateral curvature of the scoliosis facing the dominant arm occurs in 100% of the cases. It ascribed this high frequency of scoliosis with a curvature toward the dominant arm to muscular disbalance and the greater strength of the dominant arm, which is often considered the cause of scoliosis, considering the highly repetitive nature of swimming and the later adaptation of the spinal vertebra. Some researchers [23] have confirmed that asymmetric muscular growth can lead to mild scoliosis. Opposite results can be found in the work of [11], who have determined that the symmetry of the swimmers in the frontal plane is significantly better than the general population.

Muyor et al. [24] found that 68% of cyclists had hyper kyphosis. Conversely, cyclists have shown remarkable degreasing of chest kyphosis in the standing position. Similar results were obtained in the research [25], where thoracic hyper kyphosis was found in elite cyclists (58.3%) and master cyclists (53.3%). The lumbar curve was normal in 88.3% of elite and 76.7% of master cyclists. In the end, for all the participants, we had to consider the acquired habits of body posture outside the training process, how they sit, lie, carry their bags, and so on. In this study, postural disorders exist in the functional stage and, in some cases, combined disorders in athletes' sagittal and frontal planes. Therefore, it is necessary to cooperate with experts (trainers with appropriate competencies) and conduct various psychomotor analyses based on normative tests and trials [26-34].

The results of our research are just another premise for reflection (actually on the side-lines of the discussion about the health values of professional sports) about the validity of promoting sports for everyone, following the example of the most outstanding athletes and the most spectacular (often risky) sports. However, we emphasize the importance of those scientific publications that provide the latest knowledge about simple methods and means of diagnosing and counteracting the negative effects, often one-sided training loads. An example is the simple and effective 'physio training sessions method used in the training of juvenile tennis players [35]. The expectation of sports training practitioners for simple, effective diagnostic tools is well exemplified by the number of over 5,200 downloads of a work published just a few months ago [36]. The diagnosis concerns the phenomenon of the ability to optimally use muscle strength based on two very simple methods [37, 38].

In our opinion, the works referred to above are also an example of the use of the language and methodology (based on a complementary approach) of the new applied science – innovative agonology, an acronym INNOAGON (see glossary) [39-41]. Moreover, in the discussion of our research results, we tried to respect the INNOAGON language, because one of the key terms is 'development' and is used only in a positive sense [42, 43]. For health reasons, asymmetric muscle growth is not an expected effect, so the common phrase 'muscle development', also in scientific literature, would not be consistent with the actual state of affairs.

However, it was only the breakthrough discovery of Kalina et al. [44], not yet widely discussed in the scientific literature, regarding changes in human motor skills in the earliest stages of ontogenesis provides evidence of the need to move away from the 'toddlerhood and preschool motor development' paradigm. The name is appropriate: 'the first period of positive and negative changes in human motor skills already at toddlerhood and pre-school age'. Kalina et al. [44, p. 228] found that '(...) in the fourth calendar year of life: an increasing number of children, every time they fall backwards, expose their upper limbs and, to a lesser extent, their head to damage during a collision with the ground, and only a few retain the ability characteristic of the majority of two-year-olds (under these circumstances, they always protect their upper limbs and head in such a way as to avoid colliding these parts of the body with the ground (...). Thus, this phenomenon is organic in nature and the [fun form of falling] FFF-based method of revealing it makes it possible to diagnose it as early as toddlerhood'.

CONCLUSIONS

The diagnostic program results showed that the postural muscular-skeletal changes could already be detected at a young age 14 and 15 during the training process. For superior athletic performance (while protecting his health), athlete posture profiles should be monitored throughout sporting career. The pace of these changes is important. With monitoring of the athletes' profiles, early intervention can be made to keep a neutral posture and allow the athlete to continue competing with a neutral posture for optimal performance and lack of pain.

Some limitations of this study. Firstly, the participants included in the study were only male swimmers and cyclists. Therefore, the study findings should not be extrapolated to other groups e.g., female swimmers and cyclists. Secondly, this study included a small sample size. A larger sample size may be required to support current findings.

If the correct training program is adopted (one that incorporates strengthening of antagonistic muscles), a neutral posture should be maintained. This should allow athletes to maintain optimal athletic performances with minimal injuries due to posture changes throughout their careers.

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