The effect of pre-exercise standing posture on running performance in adolescent males

by

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Dissertation submitted in partial fulfilment of the requirements for the degree

MSc Sports Science

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DECLARATION

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I declare that this dissertation is my own original work. Where secondary material is used, this has been carefully acknowledged and referenced in accordance with University of Pretoria requirements.

I understand what plagiarism is and am aware of the University of Pretoria policy and implications in this regard.

D Sutcliffe	2018/09/24
SIGNATURE	**DATE**

This dissertation is dedicated to my parents

For your constant love and support. You showed me that hard work and a positive mindset are the building blocks for success.

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SYNOPSIS

Title	The effect of pre-exercise standing posture on running performance in adolescent males.
Candidate	Duncan Peter Sutcliffe
Supervisor	Dr Kim Nolte
Degree	MSc Sports Science

Limited research has focused on the possible effects of standing posture on running performance. The aim of the study was to assess the relationship between postural assessment scores and running performance results, and to further compare the postural assessment scores between participant groups (high-performance running academy and private high school athletes).

The sample consisted of athletes (n = 30) from an elite running academy and (n = 60) from a private high school in Pretoria (age = 15.51 ± 1.63 years). A modified technique of Watson and Mac Donncha which assesses eleven common areas of postural problematic areas was used.[1] Sprint speed ability was assessed using the 10, 20 and 40 metre sprint tests. The 20-metre shuttle run test (Bleep test) was conducted which assessed the aerobic endurance abilities of the participants.

Overall posture rating (mean ± SD) of the elite athlete group (48.20 ± 4.09) was higher than the private high school group (44.83 ± 4.42) (p = 0.00). The Bleep test results (mean ± SD) were also superior for the elite athlete group (10.59 ± 1.88) in comparison to the private high school group (8.26 ± 1.94) (p = 0.00). Furthermore, 10m, 20m and 40m sprint speed results (mean ± SD) were superior for the elite athlete group (1.81s ± 0.12, 3.02s ± 0.23, 5.39s ± 0.31, respectively) in comparison to the private high school group (2.07s ± 0.27, 3.50s ± 0.34, 6.35s ± 0.62, respectively) (p = 0.00). With both groups combined, moderate negative correlations were found between overall posture rating and the 20m and 40m sprint test results (r = -0.47, p = 0.00; r = -0.54, p = 0.00 respectively). Furthermore, moderate positive correlations were found between overall posture rating and the Bleep test results (r = 0.43, p = 0.00).

From the results of this study, higher overall posture ratings (better posture) were correlated with better speed and aerobic endurance. Therefore, good posture may not only have important health implications but also may be beneficial for sports performance in speed and endurance related sports and activities.

Key words: Posture, imbalance, sprint speed, aerobic endurance, elite athlete, private high-school

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GLOSSARY

- **Bipedalism -** A way of locomotion where the hind legs are independently used for movement

- **Homo erectus -** An extinct species that were able to stand upright.

- **Exercise related transient abdominal pain** - Caused by various actions that require repetitive upper body movements and is generally referred to as a stitch.

- **Maximal voluntary oxygen consumption** - A measure of an athlete's endurance capacity (cardiorespiratory fitness) which is determined during incremental exercise by measuring an individual's oxygen consumption.

- **Cervical Vertebrae** - Seven upper vertebrae which constitutes the neck region.

- **Thoracic Vertebrae** - Twelve middle vertebrae which forms the trunk region

- **Lumbar Vertebrae** - Five lower vertebrae between the rib and pelvic region.

- **Gait Cycle** - A full cycle of walking/running which is initiated by the foot touching the ground and ending when the same foot touches the ground again.

- **Neutral Spine** - This occurs when all 3 natural spinal curvatures are in the correct positions which causes the spine to be in good alignment.

- **Musculoskeletal Balance** - Arrangements of body parts relative to one another which allows for an equilibrium state.

- **Lactate Threshold** - When the intensity of specific exercise is increased, which causes the lactate build-up to occur faster than the lactate removal.

LIST OF ABBREVIATIONS

Abbreviation	Meaning
$ml.kg^{-1}.m^{-1}$	Average energy expenditure (average oxygen cost)
B.C.	Before Christ
WADA	World anti-doping agency
HPC	High Performance Centre
ETAP	Exercise related transient abdominal pain
VO_2 max	Maximal voluntary oxygen consumption
FHRSP	Forward head, round shoulders posture
GRF	Ground reaction force
BF%	Body fat percentage
C7	C = Cervical Vertebrae
T1, T3, T6, T9, T12	T = Thoracic Vertebrae
L3, L5	L = Lumbar Vertebrae
kg	Kilogram
VO_2 peak	A plateau in the human body where oxygen consumption is observed during maximum physical effort

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND INFORMATION

As foretold by Darwin, “bipedalism is the defining feature of the earliest hominins[3] and thus marks a critical divergence of the human lineage from the other apes”.[2] Rodman and McHenry further explained this finding by hypothesizing that the evolution into bipedalism was for the sole purpose of reducing the cost of locomotion in relation to the last common ancestor of chimpanzees and humans.[4] Sockol et al. clarified that the cost of transport for human walking was seventy-five percent less than chimpanzee locomotion ($mL.kg^{-1}.m^{-1}$). Therefore, hominins reduced the energy cost of walking and foraging which provided an evolutionary advantage over other apes.[5] Upright posture has been an adaptation that occurred over five million years ago. “It probably took more than five million years to make our hind limbs able to support the whole-body weight while standing”.[6]

“Evolution selected specific biomechanical features that make human locomotion mechanically efficient”.[7] Regular upright locomotion is a unique human evolutionary adaptation that occurred over a vast time frame.[8-9] It was further explained that these adaptations are caused by skeletal and muscular alterations over the course of history.[8-9] Adaptations towards an upright posture has led to increases in human endurance due to improved economy of the gait cycle, although motility was reduced.[6] Even though an erect posture is less stable compared other primates, the human brain adapted over the course of time which allows for accurate skeletomuscular adjustments which is essential for maintaining body stability.[10] “Other anatomical changes exist that increased the range of movements which could be used to stabilize the body, such as an enhanced flexibility of the spine for lower back movements”.[10]

Compliant walking is the walking style possessed by unevolved bipedal species which sustains the body’s center of mass in a fixed position during the gait cycle.[10] Although this form of locomotion is extremely stable, efficiency of movement is affected.[10] Homo Sapiens evolved to a more “stiff gait by creating a postural instability with its constant raising then lowering of the body’s center of mass”.[10] This unstable style of locomotion creates phases of body instability and thus increases the chances of tripping or falling.[10] “Striding bipedalism is a key derived behavior of hominids that possibly originated soon after the divergence of the chimpanzee and human lineages”.[11] This form of locomotion was an essential stepping stone for the evolution of walking and running. “Although bipedal gaits include walking and running, running is generally considered to have played no major role in human evolution because humans, like apes, are poor sprinters compared to most quadrupeds”.[11] The Homo erectus species adapted their physiological and physical structures which set them apart from other primate species. These adaptations included the formation of upright postures which ultimately allowed the species to participate in long-distance endurance running.[11-12] Archaeological findings suggest that endurance running is a modification of the Homo species more than 2 million years ago, which may have been a contributing factor for human evolution.[11]

Inevitably, as human movements have evolved over time, competitions were formulated to identify superior performances in sport. “A sport is defined as an activity requiring direct physical competition with an opponent(s), has established procedures and rules, and defined criteria for determining victory”.[13] “Records of competitive racing date back to the first recorded Olympic games that took place in 776 B.C. in Greece”.[14] In particular, running performances are based according to the type of running event, namely; sprints, middle distance and long distance. As the level of competition increases, so does the need for new methods to improve performances. Analysing sporting performances has been an integral part of the evolution of sport, which introduced the use of notational analysis. Hughes recognized the four functions of notational analysis as; “technical evaluation, tactical evaluation, analysis of movement and statistical compilation”.[15] A sports biomechanist is an individual who makes use of notational analytics to improve sporting performances. Various researchers explained that biomechanists predominantly focus their efforts on sports which are based around a movement technique, such as running.[16-17] “Performance enhancements can be in the form of medical or technological enhancements which opens up new possibilities for modifying the body and enhancing performances”.[18] Some medical performance enhancements may be deemed illegal in sport, which lead to the development of the World anti-doping agency (WADA) in 1999. Over a long period of time, sport has established fairly strict anti-doping rules to reduce the unwarranted use performance enhancements.[18] Illegal performance enhancements have been produced in order to attain victories in the specific sports while going against various sporting rules.

Due to the fact that running is a fundamental task, it has been labelled as the most accessible sport worldwide. Fundamental tasks like running needs to be implemented at an early age to ensure positive growth and development. It is also essential to identify all the factors that may affect running performances and general health. Posture may be one of these factors and thus formed the need to identify if a relationship exists between posture and running performances. Although posture has been identified as an important contributor towards general health, limited research has provided its direct effect on running performances.

1.2. DEFINING THE RESEARCH PROBLEM

Over the past decade, a significant amount of research has been conducted on the effects of backpacks on adolescents, as well as the long-term effects of bad posture. Deficits with regards to an individual's health or workload are commonly linked to musculoskeletal impairments, which in turn, has led to an increased interest in postural optimization.[19] It was further explained that an increased interest has been directed towards the effects of backpacks on posture.[19] Although posture is a vital aspect of general health, limited research has provided its direct effect on running performances. It is easy to categorize body posture as body shape and dimensions and look past the underlying concept of posture. Abd-Elkader and EL-Bab explained that "posture is limited to one's body shape and its outer limits".[20] In addition to this, it was further specified that "sufficient body posture is the mechanical relationship between different body organs and systems; bones, muscles and nervous".[20] If body posture is problematic, the mechanical relationships are consequently affected.

Inevitably, as the technological field is expanding, so will the regular usage of cellphones, tablets and laptops while maintaining improper posture. This may lead to the loss of normal curvature and increased stresses on the cervical spine. "These stresses may lead to early wear, tear, degeneration, and possibly surgeries".[21] According to Hansraj, completely avoiding technology is not the answer, but improving the manner of which the technology is used can be beneficial in decreasing the chances of attaining muscular imbalances.[21] It was further explained that "individuals should make an effort to look at their phones with a neutral spine and to avoid spending hours each day hunched over".[21]

It is difficult to narrow down the individual causes of running performance deficits due to its multifaceted nature, therefore, the researcher will scientifically analyse how an individual's static standing posture may affect running performances. Running with regards to speed and endurance, is an activity which requires involvement from both postural and phasic muscles. An imbalance between the two may lead to detriments in running performances. It is important to emphasize postural development from a young age to avoid negative side effects of poor posture later in life. "Many minor deviations in posture are related to problems of muscular development, and the forces produced during exercise are then unequally distributed and as a result, the chances of sustaining an injury are increased”.[22] Furthermore, postural deviations are commonly caused by individualised lifestyle patterns.[23-24] When a certain muscle group is favoured, imbalances are a common finding. Singer and Dip further emphasized this fact by explaining that muscular imbalances ultimately lead to postural problems, such as; compromised joint mechanics, resulting in compromised overall mechanics.[25] There are two types of muscles: postural and phasic.[26] Postural muscles are used for standing and walking while phasic muscles are used for running.[26] When an individual commences a gait cycle movement, specific gait mechanics request effective firing patterns from the postural muscles to maintain muscular balance and control, while the phasic muscles promote the forward movement of the runner.[26] Due to constant postural muscle activation to contest the effects of gravity, they have a tendency to shorten and become tight. In comparison, phasic muscles typically may remain in an elongated state. Runners experience long periods of constant training which may cause postural muscle tightness and shortening.[26-27] Fredericson and Moore further extrapolated this fact; “muscles which are used frequently can shorten and become dominant in a motor pattern.[26] If a muscle predominates in a motor pattern, its antagonist may become inhibited and cause a muscle imbalance”.[26] Adolescents who have not yet developed postural control, or who have developed postural control in a negative growth fashion, may not be have the necessary postural standing stability, thus having an unstable base of support for running. Stable base of support is built on a stable core structure. “A weakness or lack of sufficient coordination in core musculature can lead to less efficient movements, compensatory movement patterns, strain, overuse, and injury”.[26,28]

1.3. PURPOSE OF THE STUDY

Relationships obtained through the research procedures may help identify the link between posture and performance in running. The relationship between pre-exercise standing posture and running performance in adolescents can be used to further increase the pool of knowledge on performance parameters.

1.4. AIMS AND OBJECTIVES OF THE STUDY

Aim:

- To assess the relationship between postural assessment scores and running performance results, and to further compare the postural assessment scores between the participant groups (private high-school and a high-performance running academy).

Objectives:

- To assess the postural assessment scores of eleven postural components, running endurance results from 20m multistage shuttle run tests and running speed results from 10m, 20m and 40m sprint tests within the two participant groups (private high-school and a high-performance running academy).
- To correlate the eleven postural assessment scores, running speed results from 10m, 20m and 40m sprint tests and running endurance results from 20m multistage shuttle run tests between the two participant groups (private high-school and a high-performance running academy.

1.5. RELEVANCE AND MOTIVATION FOR THE STUDY

Performance analysis is forever growing in the world of sport. A vast amount of capital is being placed into an array of methods and techniques to better an athlete's performance, while limited effort is allocated to the structural components, namely posture. Postural promotion at a young age may have major benefits later in life, including quality of life, improved health and sporting performances. Ages 14-18 are vital stages in terms of growth and development. Various researchers believe that muscle flexibility and tightness are key determinants of body postural statuses, which are highly affected during the pubertal stages.[29-31] "It is important to remember that the stage of development of postural responses may influence the ability of the child to maintain a relaxed standing posture".[32] Although posture is a vital aspect of general health, limited research has provided its direct effect on running performances.

Posture is a component of health and performance that is severely neglected at all ages and levels of participation. Evidence has shown that good posture may have endless benefits for an individual, while postural limitations may lead to an array of problems. Lowman stated: "If steps are taken to correct malalignment or structural deviation, the individual involved will not only be protected against injury, but the efficiency of his performance will improve up to maximum capacity".[33] Many activities that promote postural growth have been substituted for sedentary activities with inadequate postural benefits. Postural deviations are commonly caused by individualised sedentary lifestyle habits.[23-24]

Postural imbalances identified may have detrimental effects on performances in an array of sporting codes, as well as the individual's general health. If postural deviations are identified, interventions can be implemented at every educational level to identify, correct and maintain postural imbalances which may prevent long term effects on the individual. In addition, specialised postural improvement programs may benefit all individuals regardless of postural statuses. Inadequate research has provided the direct effects of standing posture on running performance. As the world of sport is forever growing, so is the emphasis on performance analysis.

1.6. LIMITATIONS OF THE STUDY

The following factors could be considered as limitations to the study:

- Participants for the study were limited to elite level sprint and endurance athletes from the high-performance running academy (HPC) and students at a private high school in Pretoria.
- Some private high school participants play numerous sports, and therefore could have acquired higher fatigue levels in comparison to other participants.
- The high-performance running academy sprint and endurance athletes had different in-season and off-season periods which may have affected their performance and fatigue levels.

1.7. STRUCTURE OF THE DISSERTATION

- Chapter 1: Background information of the research study, the purpose of the study conducted, the specific objectives that were followed by the researcher, the significance of the study, and limitations overcome in the study

- Chapter 2: The theory of the research topic which is described by various information sources, which was further related to the research project.

- Chapter 3: Describes the procedures used to gather and analyse the research data. All the aspects that played a role in data collection were explained.

- Chapter 4: All research results are specified, and then further discussed so that conclusion can be made.

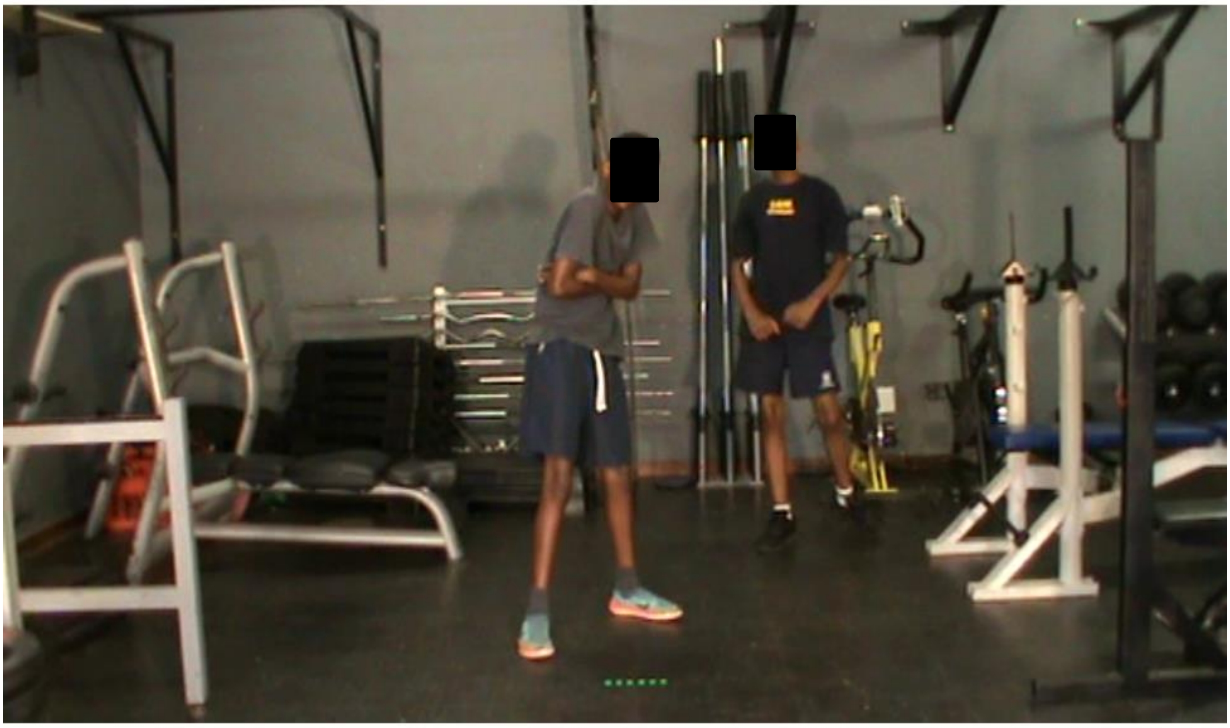
- Chapter 5: Composed of a general summary of the research study, and recommendations for future research.

- References: All research sources that were used to gather information was thoroughly referenced. This is based on the guidelines set by the University of Pretoria.

- Annexures: Consists of all the necessary documentation used before and during the testing procedures.

CHAPTER 2

LITERATURE REVIEW



2.1. INTRODUCTION

Regardless of gender or age, postural promotion strategies should be directed to acquiring a neutral spine. Postural shortcomings can be identified and corrected by conducting relatively simple exercises. Even though postural imbalances may be simple to identify and correct, more emphasis is often placed on fat loss and muscle building. Janda proposed that “the most recognisable cause of postural imbalances is sedentary lifestyle patterns”.[23] It was further explained that “sedentary lifestyle patterns are implicated to favour the postural muscles in relation to phasic muscles, thus ultimately leading to muscular imbalances”.[23] Sedentary lifestyle patters may include improper sitting, standing and lying positions.

2.2. LITERATURE OVERVIEW

2.2.1 DEFINING POSTURE:

Good posture has been defined as “a state of musculoskeletal balance that involves a minimal amount of stress or strain to the body”.[27] As an individual commences in a certain task or action, body segments are shifted to accommodate movements. As body segments shift, so does one’s posture. Watson defined good posture as “a situation when the centre of gravity of each body segment is placed vertically above the segment below”.[34] Fredericson and Moore summed up the fundamental positives of postural promotion by stating that “when the system works efficiently, the result is appropriate distribution of forces; optimal control and efficiency of movement; adequate absorption of ground-impact forces; and an absence of excessive compressive, translation, or shearing forces on the joints of the kinetic chain”.[26]

Although postural muscles have many different individual functions, the primary aim is to preserve a state of muscular balance, and therefore to ensure an upright posture.[35-36] It was further stipulated that when physical inactivity or muscular imbalances occur, postural muscles predominantly tighten, while working phasic muscles are likely to become weak.[35-36] Janda further explained that specific postural assessment strategies should be put in place to examine tightened postural muscles and weakened phasic muscles.[23,37] Furthermore, once the assessment has been conducted, treatment strategies can be planned and executed to treat muscular imbalances.[23,37] "A treatment rationale should include appropriate mobilization therapies along with improving muscle extensibility of 'tight' postural muscles and facilitating 'weakened' phasic muscles".[23,37]

Discussed below are eleven common areas of posture deviances and their relationships to running.

- Ankle/Foot Posture – Based on pronation or supination of the foot. The foot is an important factor which starts the mechanical processes of running. "A foot is positively aligned when the bisection of posterior surface of the calcaneus is perpendicular to the ground".[38] Consequently, any deviations in the foot or ankle structures will have a chain reaction effect on surrounding structures. Certain structural adaptations in the foot may have adverse effects on foot alignments, and consequently, a reduced mechanical productivity during the gait cycle.[39] The foot and ankle structures are the primary defence units against shock absorption when running. The structural composition of the foot and ankle structures are vital for load absorption, and therefore are essential to absorb the excessive loads which are shifted superiorly up the leg while running.[40] It was further explained that: "supinated feet are limited in shock absorption properties and are prone to higher stresses, while pronated feet have greater contact areas, more flexible structures and lead to decreased loads absorbed by musculoskeletal structures of the foot".[38] It was found that different shoes contain diverse cushioning strategies to combat the effects of shock absorption, and therefore, the rate of oxygen consumption varied between different shoes, with shoes having more cushioning usually being associated with lower oxygen consumption levels.[41] This finding can be related to the shock absorption properties of pronated and supinated feet structures, by providing evidence that increased shock absorption in pronated feet may lead to decreased oxygen consumption levels. When an individual has postural problems in the feet that cannot be fixed by means of cushioning strategies, orthotic devices may be used. Various authors extrapolated the effectiveness of orthotic devices, by explaining that "…reduced muscle activity, increases muscular performance, and feeling comfortable",[42-43] are just a few benefits of introducing orthotic devices to a runner. This emphasizes the effectiveness of good foot structures for the provision of good running performances.

Figure 1. Ankle/foot posture

- Knee Interspace – Based on genu varum or genu valgus positions of the knee. Clement explained that a mechanical compensation is often caused by genu varum or genu valgus, and therefore, results in a decreased mechanical efficiency due to increased muscle activations for a specific movement.[44] Knee valgus, often known as knock knees, is renowned to severely increase the lateral forces acting on the knee structure.[45] Increased forces acting on a joint often results in compensatory deficiencies and even injuries. Dierks et al. identified that a valgus position of the knee is commonly shaped by excessive femoral adduction and underdeveloped/weak hip abductors.[45] A structurally strong agonist-antagonist muscle combination of the hamstring and quadricep muscles, stabilized the knee and greatly reduced the chances of generating genu varum or genu valgus.[46] Most of the knee valgus/varum research has been aimed at promoting injury prevention, and not directed towards improving performances in sport.

Figure 2. Knee interspace posture

- Knee hyperflexion/extension – "An important determinant of the mechanics of running is the effective vertical stiffness of the body, which is escalated by increases in running speed".[47] Groucho running is a running technique where one's knee angles are reduced to decrease the vertical stiffness acting on the ankle, knee and hip joints.[47] Groucho running is a technique used by individuals who have limited shock absorption mechanisms throughout the gait cycle, and thus allow for knee hyperflexion to decrease the amount of shock absorbed. It was further stated that "Groucho running can be responsible for as much as a fifty percent increase in the rate of energy utilization, as measured by steady state oxygen consumption".[47] As human evolution has progressed, bent postures have been abandoned due to the inevitable negative effect on locomotion. Grasso et al. proposed that "in looking for the effects of posture on the locomotor patterns, we keep in mind that there exist inevitable mechanical consequences of a bent posture".[7] Biewener supported this statement by explaining that increased muscular activity results in a decreased efficiency, and therefore, resulting in a decline in the mechanical advantage during locomotion.[48] Limited research has been conducted on the relationships between knee hyperextension and running performance.

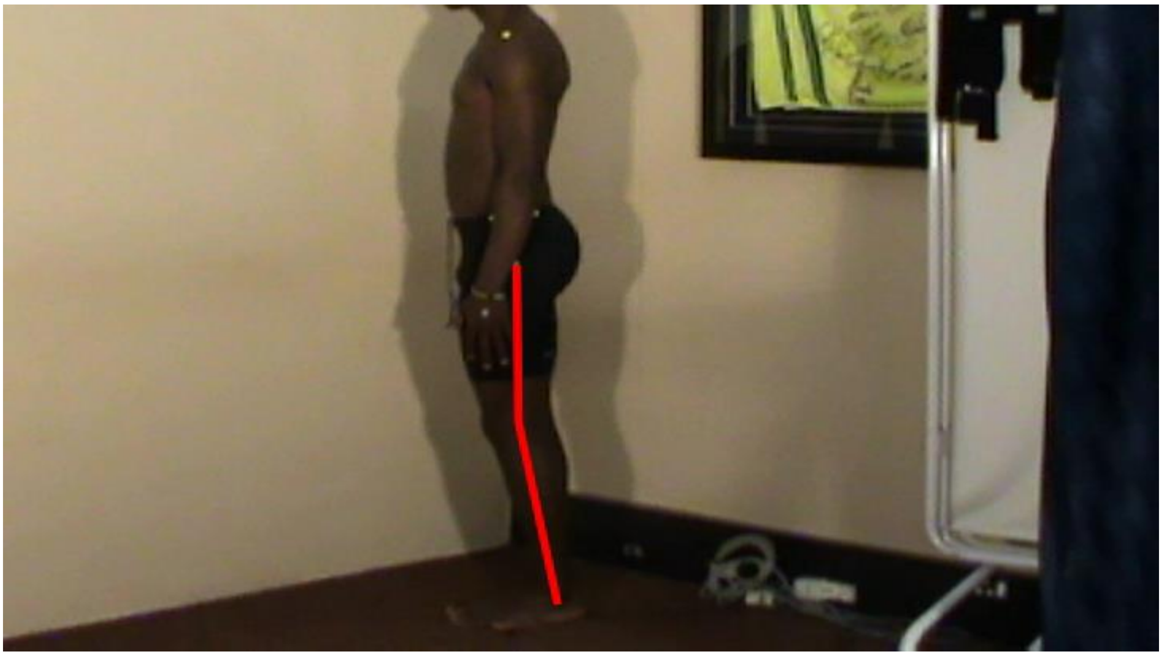


Figure 3. Knee hyperflexion posture

- Lordosis - It is commonly described that lumbar lordosis is “an increased lumbosacral angle, shortening of the hip flexors and erector spinae, and lengthening of the abdominals”.[27] Lordosis is a common postural deformation which may cause aches and discomfort in the lumbar region, especially during running. Janda suggests that low back disorders may be caused by imbalances between postural and phasic muscles, “where tightness of the hip flexors and lumbar erector muscles may inhibit gluteal and abdominal muscles to compromise lumbar spine mechanics, encouraging spinal dysfunction”.[23] Janda further specified that an individual’s running gait may also be affected due to a restriction in the hip and pelvic region due to symptoms originating from the lower back region.[23] Singer and Dip explained that insufficient abdominal and gluteal strength, as well as tight iliopsoas and hamstrings muscles are primarily the cause of lordotic postures.[25] Strong relationships have been found between lumbar lordosis and the severity of exercise related transient abdominal pain (ETAP).[49]

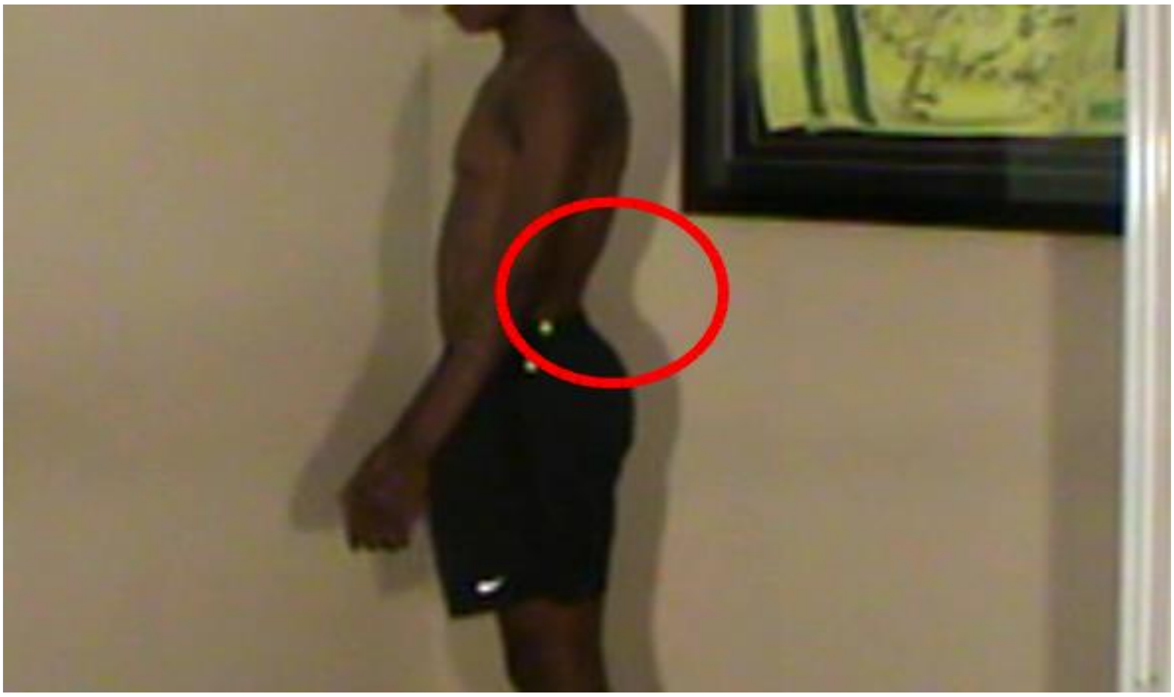


Figure 4. Lordotic posture

- Kyphosis - Rounded back and forward lean is commonly described as kyphosis. Certain sports demand repetitive movement patterns, which over time, may lead to altered anterior-posterior arches of the spine.[50] Misalignment of a thoracic segment causing kyphosis will ultimately cause a biomechanical disadvantage of functional movements.[21] Abd-Elkader and EL-Bab extrapolated that certain sport specific abilities and one's mechanical power may become compromised due to restrictions caused by kyphotic curvatures.[20] This was further explained by Watson, who related kyphotic postures to reduced lung function results, which may have adverse effects on sprint running, and even more so with endurance running.[22] Individuals with a kyphotic posture are found to be prone to regular ETAP episodes, as well as experiencing them at a greater intensity.[49] Abd-Elkader and EL-Bab identified the relationships between the severity of kyphosis and; "systolic blood pressure value (r = -0.857), diastolic blood pressure value (r = 0.898), heart rate (r = -0.741), vital capacity (r = 0.784), maximal oxygen uptake (VO_2 max) (r = -0.741), hemoglobin ratio (r = -0.714) and a direct relationship between kyphosis and lactic acid level after three minutes of exercise".[20]

Figure 5. Kyphotic posture

- Scoliosis - In a study based on scoliotic postures, one-fifth of the testing sample, who had scoliosis, also had variations in leg lengths.[25] Singer and Dip further investigated the work of various researchers on the compensatory effect of leg length variations and concluded that it may be a coping mechanism for low back pain,[51] from local spasm in iliopsoas,[52] or as a result of structural scoliosis.[53] It is essential to incorporate full range of motion and complete joint range mobility exercises to prevent muscle shortening in postural muscles, which may eventually lead to muscular imbalances and joint dysfunctions.[25] The research findings of Taylor can be related to the findings of Di-Rocco and Vaccaro who described the effect that idiopathic scoliosis has on running performance. They found that both lung function and work capacity levels were reduced.[53-54] It was hypothesized that the postural stability of individuals who have scoliosis is greatly reduced, but the running mechanics and gait patterns remain normal.[55]

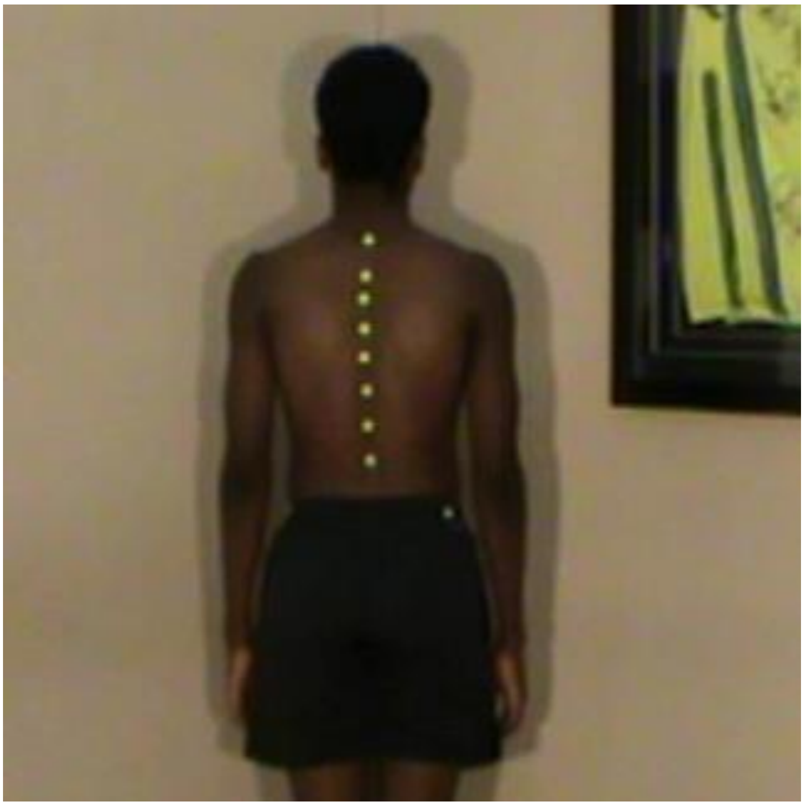


Figure 6. Scoliotic posture

- Round Shoulders and Forward head - Forward-head, rounded-shoulder posture (FHRSP) is a detailed postural irregularity that may results in unwanted pain and/or other pathological circumstances.[56] "FHRSP is defined as excessive anterior orientation of the head or glenohumeral joint relative to the vertical plumb line of the body".[57-58] As humans have adapted due to evolutionary transformations, precise biomechanical features have enabled us to become more mechanically effective with regards to gait and movement mechanics.[7] It was further stated that "for walking speeds >1 m/s, the plane orientation of bent locomotion indicates a much lower mechanical efficiency relative to erect locomotion".[7] This statement places emphasis on how human mechanical movement patterns have evolved into more efficient upright patterns due to postural changes. Cavagna et al. deduced that "erect posture is mechanically efficient in humans because the centre of body mass vaults over the supporting limb like an inverted pendulum".[59] This inhibits the loss of energy by transferring the kinetic energy into potential energy.[59] Grasso et al. concluded from research testing, that when a participant adopted a bent posture, the mean electromyography (EMG) reading was increased by all muscles involved.[7] This supports the findings by Cavagna et al. that an erect posture incorporates less muscle activation compared to a bent posture for a given movement, thus, is beneficial for endurance activities.[59] Various researchers specified that forward shoulder postures may be caused by "overdeveloped, shortened, or tight anterior shoulder girdle muscles, such as the serratus anterior, pectoralis major, pectoralis minor, and upper trapezius muscles".[27,60] Furthermore, forward shoulder postures may be triggered by weakened or stretched trapezius muscles, whose primary function is to retract the scapulae to the spine.[27,60-61] Insufficient research describes the relationships between shoulder symmetry and running performance.

Figure 7. Round shoulders posture

Figure 8. Forward head postures

- Abducted Scapulae – Culham and Peat postulated that “the resting position of the scapula is altered in subjects with abnormal cervical and thoracic spine sagittal plane arrangements”.[61] There is an inevitable relationship that exists between sprinting performances and arm swing mechanics, especially when maximal effort in produced.[62] Performance improvements with regards to sprinting may be accomplished by incorporating effective arm swing motions, which are proven to be interrelated with lower limb mechanics.[63] “When the arm-swing motion is restricted by constraining scapular motion, it clearly limits the humerothoracic extension of the backward-swinging arm.[64] As a result, the scapular constraint affects the stance-leg motion and whole-body position during the first step, thereby reducing the sprint speed”.[64] An effective approach to re-establish acceptable scapular posture and muscular activity surrounding the scapular, includes “bracing or taping the scapulothoracic articulation”.[56] Limited research has provided information linking scapulae mechanics to aerobic running endurance.

Figure 9. Abducted scapulae posture

- Pelvic Tilt – It has been elucidated that tightened iliopsoas, erector spinae, tensor fascia latae and the rectus femoris ultimately cause postural muscular imbalances, thus creating an anterior pelvic tilt.[27,65] The pelvic region is the connecting point between the legs and the upper body, and therefore requires stability and muscular balance to allow certain movement patterns to occur.[66] Massive forces are produced by the leg drive phase when running, and therefore require constant pelvic stability.[67] Anterior pelvic tilt is not only limited to decrements in performance standards but is also a major source of hamstring injuries.[68-69] Contrary to popular belief, Slocum and James hypothesized that an anterior pelvic tilt accompanied with lumbar extension may lead to improved lower leg extension capabilities, and thus increased leg thrust abilities.[70] The pelvic region requires physiological coordination from the lower limbs and spinal region for any running movements, and therefore, requires precise neuromuscular activation mechanisms.[71]

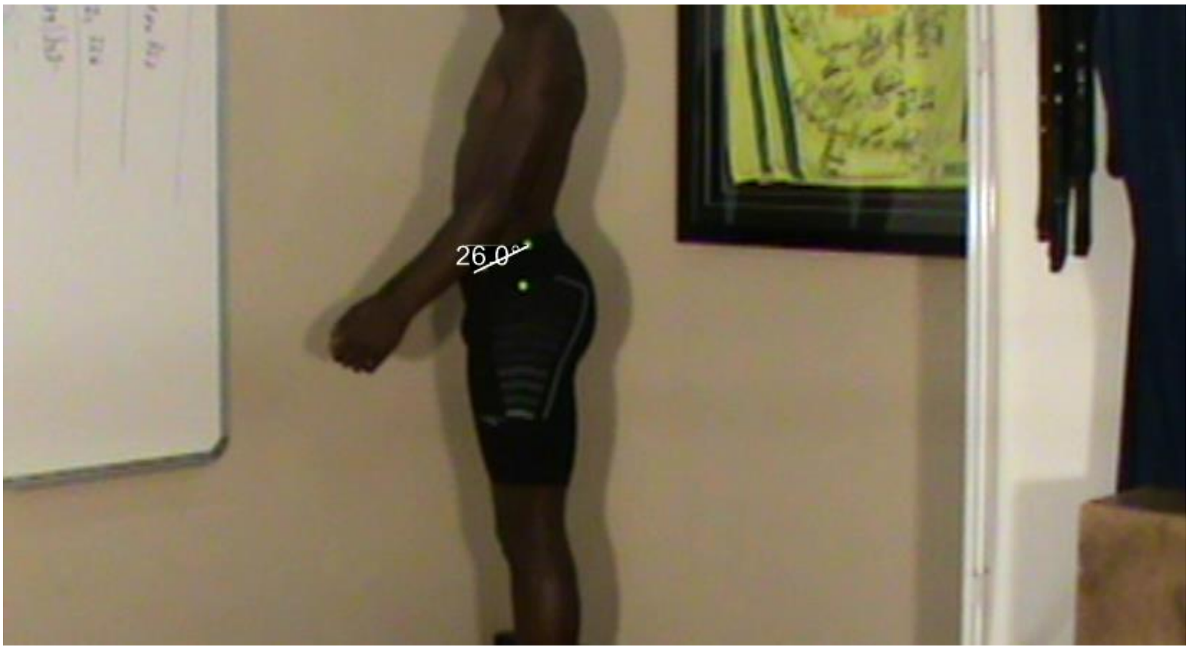


Figure 10. Pelvic tilt posture

2.2.2 DEFINING AEROBIC RUNNING ENDURANCE

Aerobic endurance exercises form part of many sporting codes and is an effective technique to maintain a good health status. "Endurance exercise training results in profound adaptations to the cardiorespiratory and neuromuscular systems that enhance the delivery of oxygen from the atmosphere to the mitochondria".[72] Core posture is a major determinant of mechanical efficiency, thus limitations in core posture may cause running endurance efficiency problems.[26] This was further emphasized by explaining that a stable core, as well as a strong foundation of muscular balance is vital for middle and long-distance runners to propel them forward when running.[26] Morton and Callister found strong relationships between postural abnormalities and ETAP.[49] ETAP is a common occurrence when high intensity running in conducted and may lead to a reduction in aerobic endurance performance standards.

- VO_2 max – Howley defined VO_2 max as "the maximal aerobic power of an individual",[73] which was further clarified by Rowell: "VO_2 max is the best measure of the functional limit of the cardiovascular system".[74] Hill and Lupton found that the rate at which oxygen is consumed during exercise is directly related to the increases of speed until maximum oxygen consumption levels are met.[75] This was further elaborated by Baechle and Earle: "As the duration of the aerobic endurance event increases, so does the proportion of total energy demand that must be met by aerobic metabolism".[76] A strong positive correlation has been shown to exist between VO_2 max and performance in aerobic endurance events.[77] Numella et al. explained that running economy is typically determined by measuring the steady-state oxygen consumption at the submaximal running speed.[78] Ray and Cureton conducted tests on the difference between standing and supine VO_2 man results in cycling.[77] Results were conclusive that standing cycling leads to a significant increase in VO_2 max results compared to supine cycling.[77] This may provide evidence that posture can hinder the oxygen delivery process to working muscles for a given task due to the structural setup of an individual. Various researchers concluded that athletes with specific spinal cord abnormalities (kyphosis, lordosis scoliosis), had reduced breathing capabilities, which ultimately affected the VO_2 max and physical performances of the participants.[20,79-81]

- Lactate threshold – Lamb stated that: “the best competitor among athletes with similar VO_2 max values are typically the people who can sustain aerobic energy production at the highest percentage of their VO_2 max without accumulating large amounts of lactic acid in the muscles and blood”.[82] Abd-Elkader and EL-Bab established direct relationships between kyphosis and lactic acid level after three minutes of exercise, by explaining that breathing complications caused by kyphotic postures ultimately diminished the waste removal efficiency, thus resulting in a build-up of lactate.[20]

- Running economy - Economical runners consume less oxygen for a given workload, and thus can sustain the given workload for longer periods of time.[78] Saunders et al. reported strong relationships between increased levels of endurance running performances and an effective running economy.[83] Numella et al. concluded that: “running economy is affected by the net vertical impulse of the ground reaction force (GRF),[84] stride length,[59] change in speed during ground contact phase,[85] and vertical stiffness of a leg spring”.[84,86] This was further explained by various researchers who stated that; “a successful endurance runner is characterized by less vertical oscillations,[87] longer stride lengths,[59] shorter ground contact times,[88] less changes in speed during the ground contact phase[85] and a lower first peak in the vertical component of the ground reaction force”.[89] According to Saunders et al. “GRF’s reflect the functional and mechanical requirements during stance”.[83] When an athlete makes physical contact with the ground, specific muscle groups will be activated for the purpose of initiating forward movement while maintaining constant stability.[83-84] Disproportionate fluctuations in momentum in various directions; “vertical, anterior-posterior and medial-lateral” may be identified as uneconomical in terms of the metabolic energy requirements.[84] Heise and Martin hypothesized that “less economical runners would exhibit greater support requirements during foot contact”.[84] Upright posture has been found to decrease the volume of muscle activation which is essential for economical running, and furthermore, “places the GRF vector nearer to the hip and knee joints and confines large moments to the ankle, where muscle fibers are short".[5] When an athlete chooses their own stride length, the gait cycle becomes more natural and therefore becomes a more economical running technique.[90] Running economy can be linked to both running technique and body structure. Watson related posture to running economy by explaining that postural alignment issues may cause increased energy consumption, and therefore reduced mechanical efficiency.[34]

2.2.3 DEFINING RUNNING SPEED

Since many sports incorporate sprint components, sprint running is an essential pre-requisite for participation in many sporting codes.[91-92] Numella et al. defined running speed as "the product of stride rate and stride length".[78] Ninety percent of speed improvements are produced through the increase of stride length, thereafter, the final ten percent of speed improvements can only be produced by increasing stride rate.[93-94] A fundamental component of running speed is the ground contact phase, where the sprinter has the ability to initiate a forceful leg drive. Since the foot makes contact with the ground, a driving force can be applied, and therefore impact the stride length and running speed. Many researchers have concluded that; as running speed increases, so does the intensity of GRF on the runner.[94-96] "Runners reach faster top speeds by applying greater support forces to the ground not by more rapid leg movements".[95] Hunter et al. described that the most important factors of sprint running are the horizontal and vertical factors.[97] "Also, of interest are the two subcomponents of the anterior-posterior horizontal GRF: a braking GRF acts posteriorly and usually occurs early in the stance phase, while a propulsive GRF acts anteriorly and usually occurs later in the stance phase".[97] General postural configurations may be an important determinant in running speed performances. Sprinters should stand upright with a forward lean to provide the body with the essential position to initiate the pushing leg drive action which is crucial for improving speed.[66,95] It was concluded that, in order to increase the aerial time and forward propulsion, one must incorporate larger forces upwards against gravity.[95] This could also be accomplished through consistent arm actions, which promotes between five and ten percent of the entire lift force throughout the gait cycle.[98]

2.2.4 ASSESSING POSTURE

Watson and Mac Donncha emphasized the fact that posture is inevitably and important factor of health and performance but is also an extremely difficult aspect to assess.[1] Posture is a very complicated aspect to measure because imbalances may be extremely minuscule, which is difficult to identify with the human eye. Ruivo et al. stated that: “postural assessments through photography may be a simple method that allows the acquisition of quantitative values to define the alignment of body segments”.[99] “Static photographic analysis with reflective markers placed on specified anatomical landmarks may be more suited to large-scale studies”.[100] “This is because it is relatively cheap, requiring only a camera, markers and adhesive tape; is highly portable; and permits the measurement of several posture angles simultaneously”.[100] Weber et al. further emphasized this fact by stating: “photogrammetry is the most widely used method for noninvasive measurement of postural measures, as it eliminates the risk of exposure to harmful radiation encountered with the radiographic method”.[101] Photogrammetry is a method of assessment used by many sport and health related specialists. It allows for the quantification of a postural assessments by assessing various angles and distances by means of specialized software programs.[101-102] X-Rays may be an accurate method of postural assessments, but is found to be extremely expensive, time consuming and can only assess a single postural aspect at a time. It was explained that “recent technology improvements have paved the way for a development of highly reliable and applicable methods, such as low-dose x-ray scanning (Lodox Systems Ltd, Johannesburg, South Africa)”.[103] “The Wickens Kiphuth procedure is effective for the assessment of antero-posterior aspect of posture, but participant preparation is time consuming”.[1] In a research study conducted by Arnheim et al., postural imbalances and assessment methods were partially explained, but extremely limited explanations were given on the reliability of the methods used.[104] One of the more popular field methods of postural assessments is the New York posture rating scale. It is a very simple qualitative method that uses three pictures for each of the thirteen postural areas being assessed.[105] These pictures are extremely vague, and no evidence is provided on their origin and formulation. Watson and Mac Donncha stated that the New York posture rating scale “has no specific defining criteria assigned to each posture category”,[1] which makes it difficult when assessing miniscule postural imbalances. The Watson and Mac Donncha technique clearly indicates which postural aspect is being identified for each diagram, while the New York rating scale includes more than one postural area per diagram. Furthermore, the New York posture rating scale is only a qualitative assessment measure. This could increase the chances of interrater reliability, while the Watson and Mac Donncha technique uses a combination of quantitative and qualitative measures to ensure the most valid results.

The technique used by Watson and Mac Donncha had a “reproducibility of postural scores that exceeded 85% for all the aspects assessed”.[1] It was further explained that the techniques used are appropriate for researching the relationships between posture and various other variables.[1] Furthermore, the research methods accurately evaluated the most prominent posture aspects in an effective an efficient manner.[1]

2.2.5 COMPLICATIONS OF POOR POSTURE

Kendall et al. stated that: “poor posture is a faulty relationship of the various parts of the body which produces increase strain on the supporting structures and in which, there is less efficient balance of the body over its base of support”.[27] Increased strain to surrounding structures may have consequential effects on running performances. It is important to remember that there may be multiple causes of postural imbalances at a given time, with many resulting consequences. An individual’s posture is a critical component of regular balance,[106] while research illustrates that postural imbalances are extremely common in adolescents.[107] “Posture of adolescents can be affected by both internal and external influences, which may make adolescents more susceptible to injury”.[108] A disruption in regular postural development during pubertal stages can lead to harmful developments later in life.[109] According to Tattersall and Walshaw: “postural deviations alter the body mechanics, causing uneven pressure on joint surfaces and ligament strain”.[110] Running performance standards are strongly linked to a certain set of structural characteristics and body mechanics which is due to certain exercises/movements requiring similar biological tissue configuration.[111] Tattersall and Walshaw explained that individuals with poor posture may acquire weaknesses in the antigravity muscles in conjunction with the weakened antagonists of tightened muscles, which is considered a muscular imbalance.[110] According to Weyand and Davis, there are numerous consequences of having a poor posture and often require corrective exercises.[111] It was further elucidated that imbalances need to be corrected by strengthening the weakened muscles.[110] Initially, a muscular imbalance is found to be a functional problem, which is further developed into a structural alteration.[112] Muscular imbalances initially affect the muscles, cartilage and ligaments, and eventually affects the bones and joints of an individual.[112] "The latter is known as fixed postural abnormalities which is commonly associated with blocks and pain, which often requires medical treatment".[112] When the imbalance is still in the functional abnormality stage, corrective muscular exercises which are specific to the imbalances of the individual can lead to beneficial results and improvements.[113-115]

In addition, physical components are only one side of the spectrum. Poor posture along with low body weight may reinforce poor body image and reduce self-confidence".[110] Watson further clarified the mental side of postural imbalances by stating that: "individuals with poor posture look less well and are more likely to have a poor self-image and self-confidence".[22] Self-confidence has a major role in the mental state of the individual during sporting preparations and competitions.

CHAPTER 3

METHODOLOGY AND DESIGN

3.1. INTRODUCTION

Many research studies have been based around the effects of backpacks on adolescents, as well as the long-term effects of bad posture.[19] Limited research has identified the direct relationships between posture and running performances. The researcher followed a specified method and study design which scientifically analysed the correlational and comparisons between the participant groups. The methodology and design for the research study was based around three main testing procedures, namely; postural assessments, sprint tests and endurance tests. Stated below are the materials and methods that were used to gather data. This includes the study design, population and sampling, measurements and procedures, data analysis, ethical considerations and facilities and equipment.

3.2. STUDY DESIGN

A cross-sectional, descriptive, correlational study design was followed. The relationships that existed between postural assessment scores and running performances, namely: the 10, 20 and 40-meter sprint test as well as the 20-metre shuttle run test (bleep test) was examined.

- Cross sectional aspect - Involved the examining of data from two participant groups (high performance running academy and private high school) at a given point in time.
- Descriptive aspect - The study was descriptive in nature as the relationship observed between the postural assessments and running performance was thoroughly described.
- Comparative aspect - The researcher compared the postural scores between the high-performance running academy and the private high school participants to identify whether superior running performances may be linked to postural scores. Furthermore, there was also a comparison conducted between the high-performance running academy sprint athletes and the high-performance running academy endurance athletes.

3.3. POPULATION AND SAMPLING

Participants were recruited from a private high school and a high-performance running academy in Pretoria. Participants and parents/guardians were informed of the requirements of the study and asked to complete an informed consent/assent form before the testing date. Participants were placed into ten-kilogram weight categories instead of age groups to negate the effects of pubertal influences on running results.

- The first 60 healthy male students between the ages of 14 and 18 from a specified private high school that met the inclusion criteria voluntarily participated in the study.
- 15-20 healthy male sprint athletes between the ages of 14 and 18 from the high-performance running academy that met the inclusion criteria voluntarily participate in the study.
- 15-20 healthy male endurance athletes between the ages of 14 and 18 from the high-performance running academy that met the inclusion criteria voluntarily participated in the study.

Inclusion criteria

- Healthy male high-school students from a private school in Pretoria.
- Healthy male sprint and endurance athletes from a high-performance running academy.
- All ethnic and racial groups were open to volunteer.
- Participants couldn’t have any current injuries or illnesses that prevented maximal effort in performance testing. Confirmation was obtained from relevant coaching/managerial staff.

Exclusion criteria

- Individuals who had any injuries or illnesses that may have prevented maximal effort in performance testing.
- Females weren’t allowed to participate in the study.
- Individuals with body fat percentages (BF%) other than the prescribed healthy

fitness zone (7.0% – 22.2%), weren't allowed to participate in the study (Appendix 1).

- Individuals who had muscle soreness or stiffness from various other sporting activities, that may have prevented maximal effort in performance testing.
- Any individuals who failed to meet the inclusion criteria.

3.4. MEASUREMENTS AND PROCEDURES

Three tests were conducted and included:

- 10, 20 and 40 metre sprint tests using a photoelectric light system was conducted to assess the sprint speed abilities of participants (Smart Speed Pro, Fusion Sport, Chicago Illinois). All sprint tests were conducted on outdoor grass fields after school time. Some testing days varied in ambient temperature.
- A modified technique of Watson and Mac Donncha, which qualitatively and quantitatively assessed eleven common areas of postural problematic areas was performed.[1] Environmental conditions were maintained by ensuring that all the postural assessments were conducted indoors after school time.
- The 20-metre shuttle run test using a pre-recorded audio track and a speaker system was used to assess the aerobic endurance abilities of the participants (Australian Bleep Test Version). All the 20-metre shuttle run tests were conducted on outdoor grass fields after school time. Some testing days varied in ambient temperature

Three separate days were used to conduct the full spectrum of testing procedures for each participant. Testing day one (sprint speed assessment), testing day two (postural assessment) and testing day three (aerobic endurance assessment). A minimum of 24 hours was given between each speed and endurance test. Before each speed and endurance testing session, a standardized warm-up of ten minutes was conducted that primarily included jogging, running and dynamic stretches. The purpose was to increase muscle/tendon flexibility, minimizing injury, enhance athletic performance, and generally preparing the participants for the workload ahead. For increased reliability, relationships between weight divisions was used as an alternative to age group divisions to rule out the effects of pubertal influences (ten-kilogram weight divisions). BF% was also used in coherence with the exclusion criteria to rule out effects of body fat on running performance results, and thus ensuring valid results (Appendix 1).[116] The BF% of all participants was tested prior to research testing by the sport science staff at the given facilities (private high school and high-performance running academy). The sum of 7 skinfolds was assessed at both facilities which was used to calculate BF%.[117] Pre-participation explanations for each testing session was executed to ensure reliable results and a clear understanding of procedures. The results from the three days of testing were obtained and recorded on the data collection sheets (Appendix 2-4).

3.4.1 TESTING DAY ONE (SPRINT SPEED ASSESSMENT)

Testing on day one was conducted in one session per age group at the private school, and in one session for all the high-performance running academy athletes. BF% and body mass was assessed prior to speed testing. The photoelectric light systems were used to assess the sprint abilities of the participants. Sprint assessments for 10m, 20m and 40m was measured. Each distance marker contained one Smart Speed light to measure the time taken to reach that point. Participants were instructed to sprint maximally throughout the allocated distances without stopping or slowing down. Values were recorded in (seconds) for completing allocated distances. The better of two attempts per participant was recorded for data collection. All participants were instructed to wear comfortable training shorts, a comfortable training shirt and regular running shoes. No running spikes or barefoot running was permitted.

Figure 11. The set up for sprint speed assessments

3.4.2 TESTING DAY TWO (POSTURAL ASSESSMENT)

Postural assessments were conducted using both qualitative and quantitative measures. A high-quality high-definition (HD) video camera was placed perpendicular and centrally 10ft (3,048 metres) from the platform at a height of 120 centimetres.[1] The camera was horizontally and vertically levelled using the tripod spirit level. Software generated plumb lines were used instead of the reference method's free hanging plumb lines. Footage recorded was in the form of video recorded data instead of photographs for the sole purpose that minor movements may have altered the postural scores. The landmarks were marked before testing with the use of adhesive dots. This enabled the researcher to accurately measure and/or calculate certain values for postural scoring. The landmarks were as follows; patellar notch, greater trochanter, both clavicular heads, both iliac spines, tibial tuberosity, centre of the patellae, C7/T1, T3, T6, T9, T12, L3, L5, most prominent point of the sacrum and the centre of the calcaneus.[1] Participants were asked to stand completely relaxed, upright, staring ahead with their chin parallel to the ground (Frankfort plane) and their elbows and knees fully extended.[1] Fingers and thumbs were pointed forward and the participant's heels were touching. When instructed, the participant would rotate and stand 90 degrees clockwise; this was repeated so that the anterior, lateral and posterior aspect of the participant was recorded.[1] All participants were instructed to remove all items of clothing, except ski-pants that sit tight on the skin. No shoes or socks were worn during the postural assessment. The participants obtained a postural rating of five, three or one for each postural area (ankle posture, knee interspace, knee hyperextension/flexion, lordosis, kyphosis, scoliosis, round shoulders, abducted scapulae, shoulder symmetry, forward head and pelvic tilt).[1] "A score of five corresponds to good body mechanics that ranges from no deviation to a level just above that of the previous category. A score of three corresponds to a moderate deviation and a score of one corresponds to a marked deviation".[1] An overall score of 55 from all 11 postural components corresponds to a perfect posture. The postural assessment procedure was conducted by the researcher, as well as a qualified Dartfish technologist. This was done separately for the purpose of attaining an objective view and thus decreasing the chances of biased results. Conflicting results were re-assessed until both analysts were in agreeance.

- The first procedure involved observing one or two scoring criteria photographs to designate a participant to a qualitative posture category.[1] The 11 separate aspects which were assessed are as follows: ankle posture (Appendix 5), knee interspace (Appendix 6), knee hyperextension/flexion (Appendix 7), lordosis (Appendix 8), kyphosis (Appendix 9), scoliosis (Appendix 10), round shoulders (Appendix 11), abducted scapulae (Appendix 11), shoulder symmetry (Appendix 12), forward head (Appendix 13).[1]
- The second procedure involved the superimposing of scoring criteria photos from the Watson and Mac Donncha method onto the videos of participants using Dartfish Pro software (version 8 and 9) (Appendix 5 - 13).[1] A 30cm ruler was presented in all the video footage so that the software calibration was accounted for and the scaling was precise.
- The third procedure was conducted to either support or reconsider the qualitative judgement, which involved the use of quantitative methods of assessment.[1] The analysis of video captured footage in a quantitative method was conducted using Dartfish Pro (version 8 and 9). This allowed for pinpoint analysis of postural deviances and thus furthers the validity of results. The third procedure was the deciding deduction if the first and second postural procedures were conflicting.

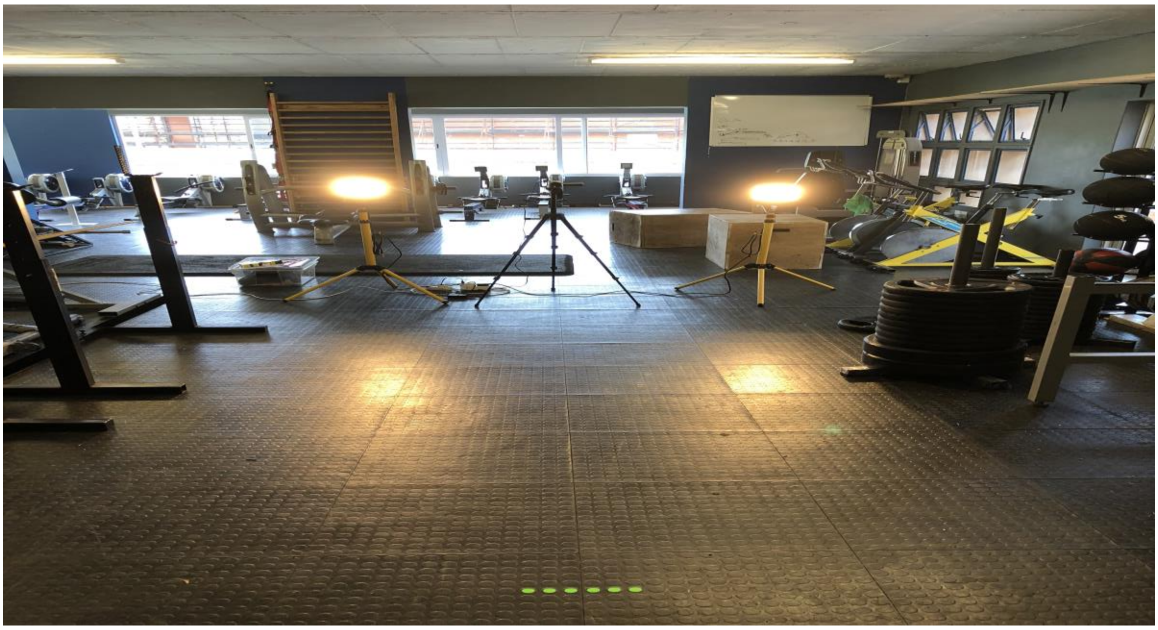


Figure 12. The set-up for postural assessments

3.4.3 TESTING DAY 3 (AEROBIC ENDURANCE ASSESSMENT)

The high-performance running academy group testing was conducted in one session and took place after school time as part of their interim testing. Testing at the specified private school was conducted in multiple testing sessions during the physical education periods due to the large number of participants. The 20m shuttle run test (bleep test) was conducted in accordance to Leger and Lambert (Figure 13).[118] The participants ran between two lines in the allocated timeframe which was situated 20m apart. The speed started off slow but increased gradually. If the line was not reached before the beep sounds, a warning was given. The test was stopped if the participant didn't reach within three metres of the line,[118] or two consecutive warnings were obtained. The tests took place on grass fields for all participants. Scores obtained are in the form of running levels.[118] All participants were instructed to wear comfortable training shorts, a comfortable training shirt and regular running shoes. No running spikes or barefoot running was permitted.

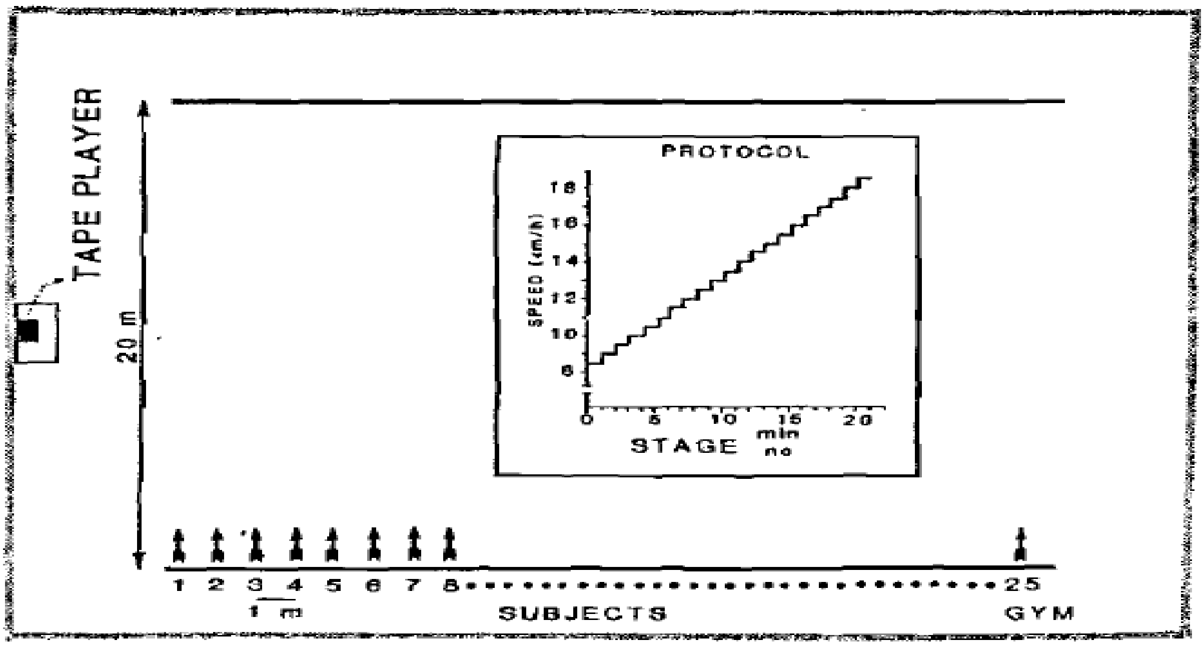


Figure 13. The 20m shuttle run test

3.5. DATA ANALYSIS

An independent statistician from the South African Medical Research Council (SAMRC) assisted with the statistical analysis. Descriptive statistics were used to describe the participants and assessment results. The statistical tool that was used was Strata 14.2 (Strata Worldwide). Significance was set at $p < 0.05$, and the data is illustrated in tables and graphs. Data captured from all the participants that complied with all the criteria of the testing procedures was analysed.

Pearson product-moment correlation coefficient was used to examine the strength of relationships between different postures and running performances (10m, 20m, 40m and bleep test). The co-efficient of determination (r) is reported. The closer r is to ± 1 the stronger the monotonic relationship.[119]

- 0.00 - 0.19 ‘very weak’
- 0.20 - 0.39 ‘weak’
- 0.40 - 0.59 moderate
- 0.60 - 0.79 ‘strong’
- 0.80 - 1.00 ‘very strong’

Tabstat was used to identify summary statistics (mean and standard deviation) for all measurements within each participant group and athlete type. Two-sample t test with unequal variances was used as a measure of comparison between participant groups. Bonferroni correction tests were used to assess all running performance results (10m, 20m, 40m and bleep test) and postural assessment results between weight categories. Furthermore, Bartlett's test for equal variances was used to present the outcome measures (10m, 20m, 40m and total posture) between weight categories. Kruskal-Wallis equality-of-populations rank test was used to assess the correlation level changes at each individual group, sub-group level and weight category.

3.6. ETHICAL CONSIDERATIONS

Faculty of Health Sciences MSc Committee and Research Ethics Committee clearance was obtained before the commencement of the research study. Protocol number 141/2017 (Appendix 14). Informed consent/assent from the participants' parents and/or guardians were collected before testing (Appendix 15-16). A thorough verbal explanation of all assessments as well as a full briefing session was given to all the participants, and all questions were answered by the researcher.

Risks associated with participation in the study was explained to the participants and included, but was not limited to, muscle pain, muscle stiffness, fatigue, and in rare instances dizziness. The risks associated with the study were based primarily on the sprint and endurance tests which required maximal efforts, and thus increased susceptibility of injuries. Participation in the study remained voluntarily; this was made clear in the explanation and consent/assent forms. The participants could stop the tests at any time if necessary.

Risks were reduced by the implementation of an in-depth explanation of all testing procedures and the participants were required to perform a warm-up. Anonymity was maintained throughout the full testing procedure using a numbering system. The names of the participants will not be published or presented. Confidentiality will also be ensured, and the raw data will be stored for up to 15 years (Appendix 17). The video recorded footage was only seem by the primary researcher and the supporting video analyst. Recorded footage will be stored in a secure place and will not be visually published in any way.

3.7. FACILITIES AND EQUIPMENT

Research testing was conducted at two different facilities;

- The high-performance running academy facility allowed for testing to take place on a selected sports field in conjunction with the biomechanics video analysis room. Testing took place after school time as part of the interim year testing. Prior permission to use these facilities was obtained via a written letter (Appendix 18).
- The private high school allowed for testing to take place on a designated sports field in conjunction with a video analysis room. Testing took place during the physical education periods during the school day. Prior permission to use these facilities was obtained via a written letter (Appendix 19).

Research equipment that needed permission and clearance (Appendix 20-21);

- Smart Speed (Smart Speed Pro, Fusion Sport)
- Bleep test soundtrack (Australian Bleep Test Version)
- Dartfish (Dartfish connect plus, version 8 and 9)

3.8. CONCLUSION

Chapter three explained all the methodologies used to collect the relevant data, and the study design that was followed by the researcher to attain valid and reliable results.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. INTRODUCTION

Parameters that were taken into account for statistical purposes, are fully discussed in this chapter. Data was analysed using a variety of statistical tests as previously mentioned in the data analysis section. Results are illustrated in graphs and tables and then further explained in the discussion section.

4.2. RESULTS

4.2.1. PARTICIPANT INFORMATION DESCRIPTIVE STATISTICS

As shown in Figure 14, the research study included two main groups (age = 15.51 ± 1.63 years), namely: a private high school (n = 60) and high-performance running academy athletes (n = 30). The high-performance running academy group was divided into HPC sprint (n = 15) and HPC endurance (n = 15) athlete types.

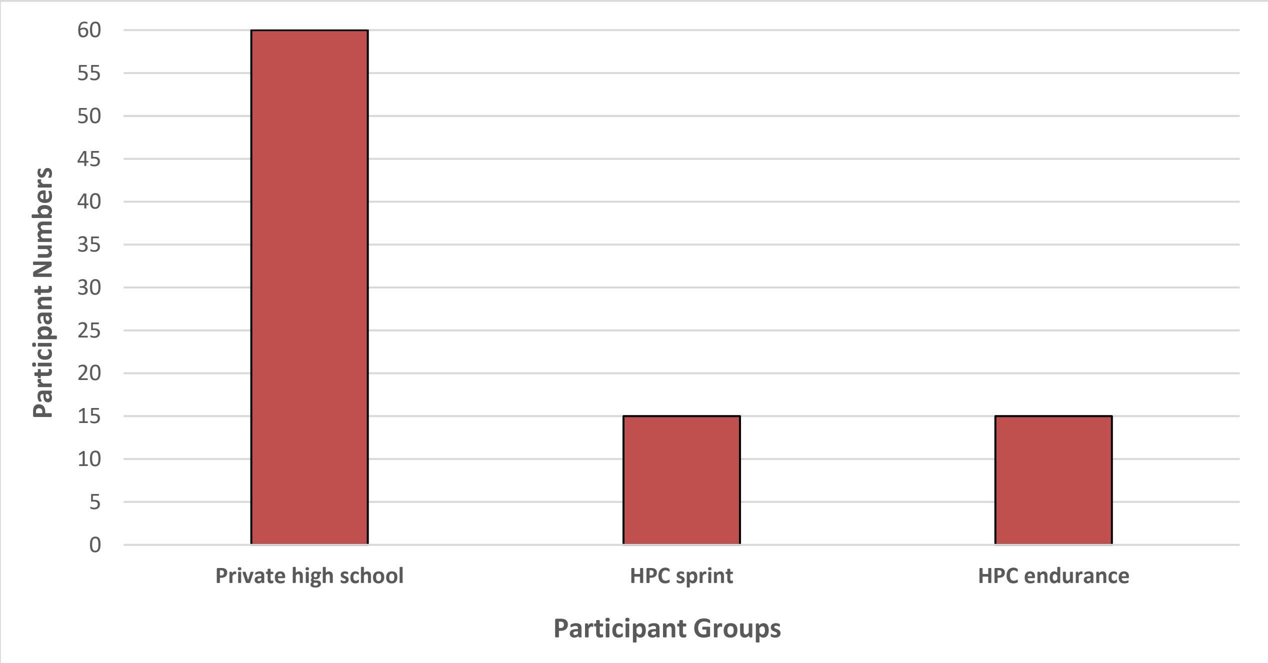


Figure 14. Participant numbers included in the research study (n = 90)

Table 1 – Demographic data for the three participant groups

Group	Grade	Age (years)	Mass (kg)	Number of sports
HPC Sprint (Mean ± SD)	10.33 ± 1.30	16.47 ± 1.32	67.30 ± 5.90	1.00 ± 0.00
HPC Endurance (Mean ± SD)	10.07 ± 1.24	16.20 ± 1.11	58.00 ± 6.63	1.00 ± 0.00
Private high school (Mean ± SD)	9.82 ± 1.60	15.10 ± 1.69	64.10 ± 13.42	2.70 ± 0.49
Total (Mean ± SD)	10.07 ± 0.21	15.92 ± 0.59	63.10 ± 3.86	1.57 ± 0.80

Table 1 illustrates that the grade, age, mass and number of sports (mean ± SD) of the three participant groups was (10.07 ± 0.21, 15.92 ± 0.59, 63.10 ± 3.86, 1.57 ± 0.80, respectively) ($p < 0.05$).

4.2.2. DIFFERENCES BETWEEN PARTICIPANT GROUPS DESCRIPTIVE STATISTICS

Table 2 - Summary statistics for the measurements by participant group

Group	10m (s)	20m (s)	40m (s)	Bleep	Total Posture
HPC (Mean ± SD)	1.81 ± 0.12	3.02 ± 0.23	5.39 ± 0.31	10.59 ± 1.88	48.20 ± 4.09
Private high school (Mean ± SD)	2.07 ± 0.27	3.50 ± 0.34	6.35 ± 0.62	8.26 ± 1.94	44.83 ± 4.42
Total (Mean ± SD)	1.98 ± 0.26	3.34 ± 0.38	6.03 ± 0.70	9.04 ± 2.21	45.96 ± 4.58

Table 2 and Figure 15 illustrate that the 10m, 20m and 40m sprint test results (mean ± SD) were superior for the high-performance running academy group (1.81s ± 0.12, 3.02s ± 0.23, 5.39s ± 0.31, respectively) in comparison to the private high school group (2.07s ± 0.27, 3.50s ± 0.34, 6.35s ± 0.62, respectively) ($p < 0.05$).

Figure 16 shows that the bleep test results (mean ± SD) was also superior for the high-performance running academy group (10.59 ± 1.88) in comparison to the private high school group (8.26 ± 1.94) ($p < 0.05$).

The total posture scores (mean ± SD) of the high-performance running academy group (48.20 ± 4.09) was higher than the private high school group (44.83 ± 4.42) ($p < 0.05$).

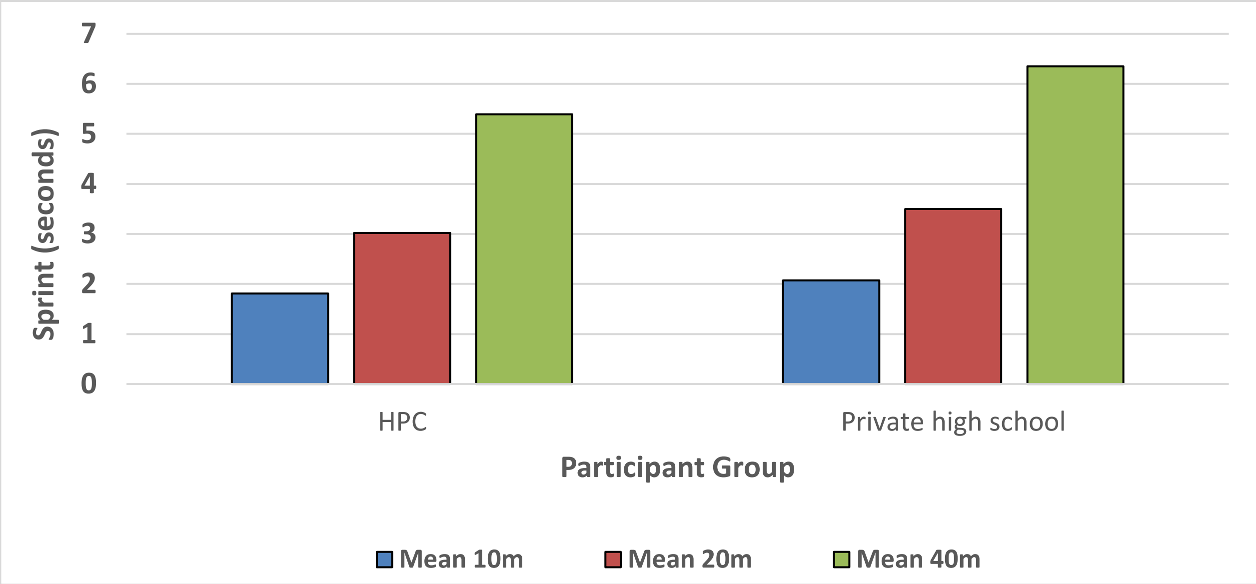


Figure 15. Bar chart of 10m, 20m, 40m sprint results by participant group (n = 90) ($p < 0.05$).

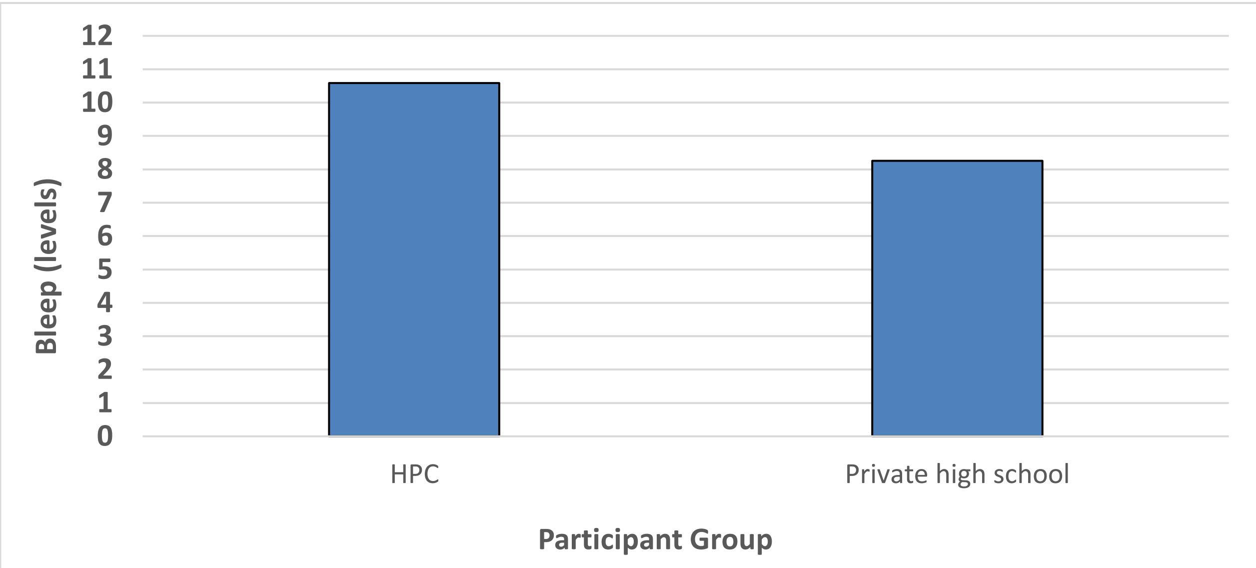


Figure 16. Bar chart of the bleep test levels by participant group (n = 90) ($p < 0.05$).

4.2.3. DIFFERENCES BETWEEN ATHLETE TYPE DESCRIPTIVE STATISTICS

Table 3 - Summary statistics for the measurements by athlete type

Group	10m (s)	20m (s)	40m (s)	Bleep	Total Posture
HPC Endurance (Mean ± SD)	1.88 ± 0.11	3.16 ± 0.15	5.60 ± 0.25	11.90 ± 1.53	47.27 ± 4.13
HPC Sprint (Mean ± SD)	1.73 ± 0.09	2.88 ± 0.22	5.18 ± 0.20	9.29 ± 1.17	49.13 ± 3.96
Private high school (Mean ± SD)	2.07 ± 0.27	3.50 ± 0.34	6.35 ± 0.62	8.26 ± 1.94	44.83 ± 4.42
Total (Mean ± SD)	1.98 ± 0.26	3.34 ± 0.38	6.03 ± 0.70	9.04 ± 2.21	45.96 ± 4.58

Table 3 and Figure 17 illustrate that the 10m, 20m and 40m sprint results (mean ± SD) were superior for the HPC sprint group (1.73s ± 0.09; 2.88s ± 0.22; 5.18s ± 0.20) in comparison to the HPC endurance group (1.88s ± 0.11; 3.16s ± 0.15; 5.60s ± 0.25) and private high school group (2.07s ± 0.27; 3.50s ± 0.34; 6.35s ± 0.62) ($p < 0.05$).

Figure 18 shows that the bleep test results (mean ± SD) were superior for the HPC endurance group (11.90 ± 1.53) in comparison to the HPC sprint group (9.29 ± 1.17) and private high school group (8.26 ± 1.94) ($p < 0.05$).

The total posture results (mean ± SD) were superior for the HPC sprint group (49.13 ± 3.96) in comparison to the HPC endurance group (47.27 ± 4.13) and private high school group (44.83 ± 4.42) ($p < 0.05$).

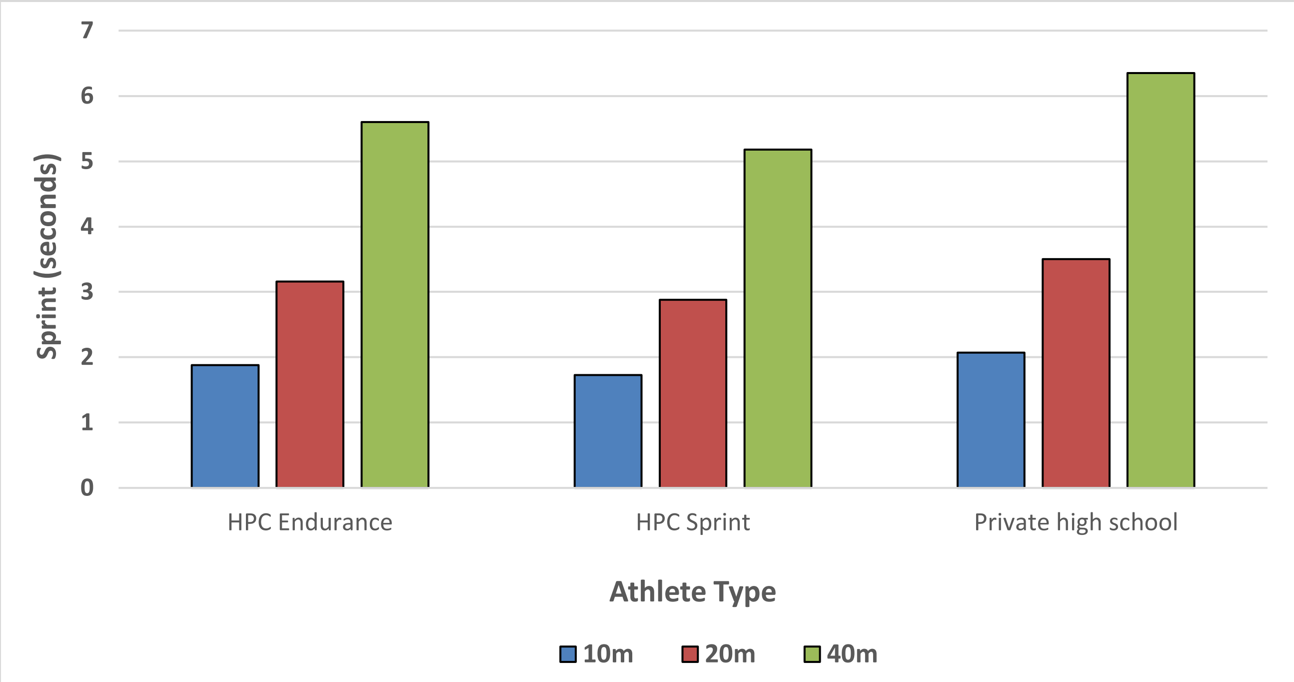


Figure 17. Bar chart of 10m, 20m, 40m sprint results by athlete type (n = 90) ($p < 0.05$)

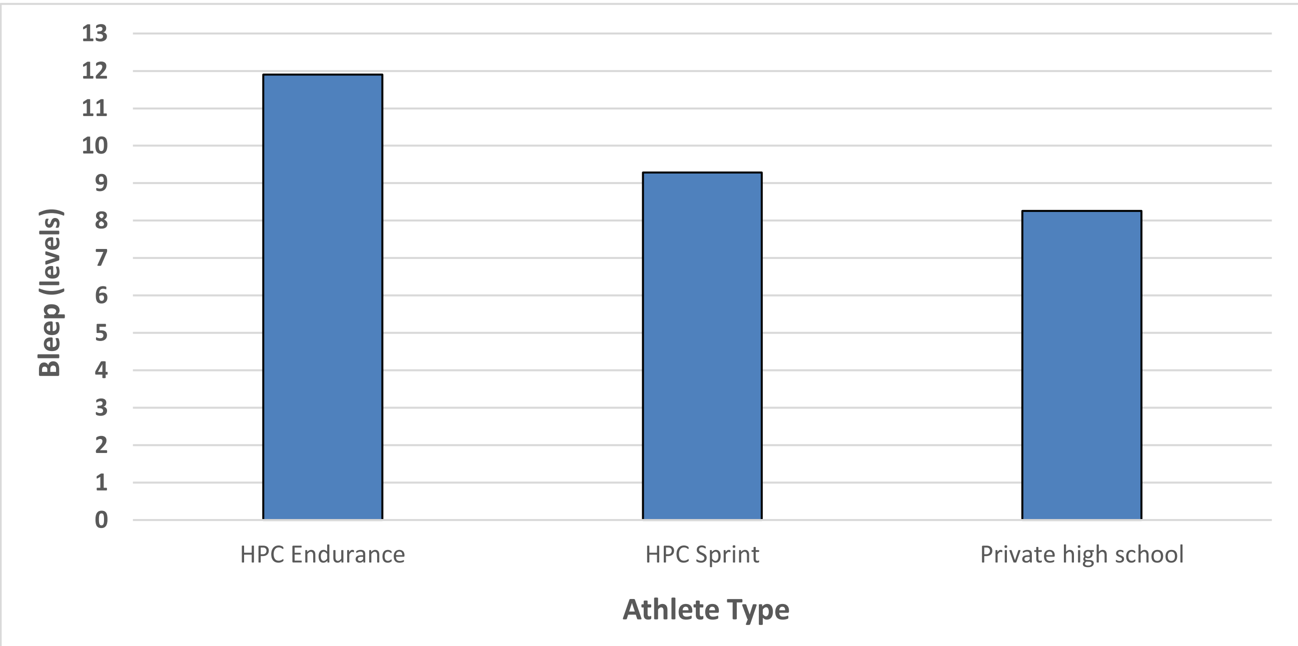


Figure 18. Bar chart of bleep test levels by athlete type (n = 90) ($p < 0.05$).

4.2.4. DIFFERENCE IN WEIGHT CATEGORIES DESCRIPTIVE STATISTICS

Table 4 - Summary statistics for the measurements by weight category

Weight category (kg)	10m (s)	20m (s)	40m (s)	Bleep test	Total posture
40-50 (Mean ± SD)	2.14 ± 0.23	3.66 ± 0.32	6.69 ± 0.64	8.10 ± 1.47	41.00 ± 3.52
50-60 (Mean ± SD)	2.02 ± 0.26	3.40 ± 0.40	6.05 ± 0.69	9.50 ± 2.56	46.89 ± 5.71
60-70 (Mean ± SD)	1.92 ± 0.91	3.26 ± 0.39	5.89 ± 0.67	9.40 ± 2.01	46.77 ± 3.84
70-80 (Mean ± SD)	1.85 ± 0.13	3.13 ± 0.21	5.60 ± 0.41	9.30 ± 1.77	47.47 ± 3.20
80+ (Mean ± SD)	2.22 ± 0.49	3.56 ± 0.34	6.57 ± 0.61	6.80 ± 2.17	44.14 ± 3.63

Table 4 and Figure 19 illustrate that the 70-80-kilogram (kg) weight category was superior in the 10m (1.85s ± 0.13), 20m (3.13s ± 0.21) and 40m (5.60s ± 0.41) sprint test results (mean ± SD) in relation to the other weight categories ($p < 0.05$).

Furthermore, figure 20 shows that the 50-60-kilogram (kg) weight category was superior in the bleep test results (mean ± SD) (9.50 ± 2.56) in comparison to the 40-50kg (8.10 ± 1.47), 60-70kg (9.40 ± 2.01), 70-80kg (9.30 ± 1.77) and 80+kg (6.80 ± 2.17) weight categories ($p < 0.05$).

The total posture results (mean ± SD) were superior for the 70-80kg weight category (47.47 ± 3.20) in comparison to the 40-50kg (41.00 ± 3.52), 50-60kg (46.89 ± 5.71), 60-70kg (46.77 ± 3.84) and 80+kg (44.14 ± 3.63) weight categories ($p < 0.05$).

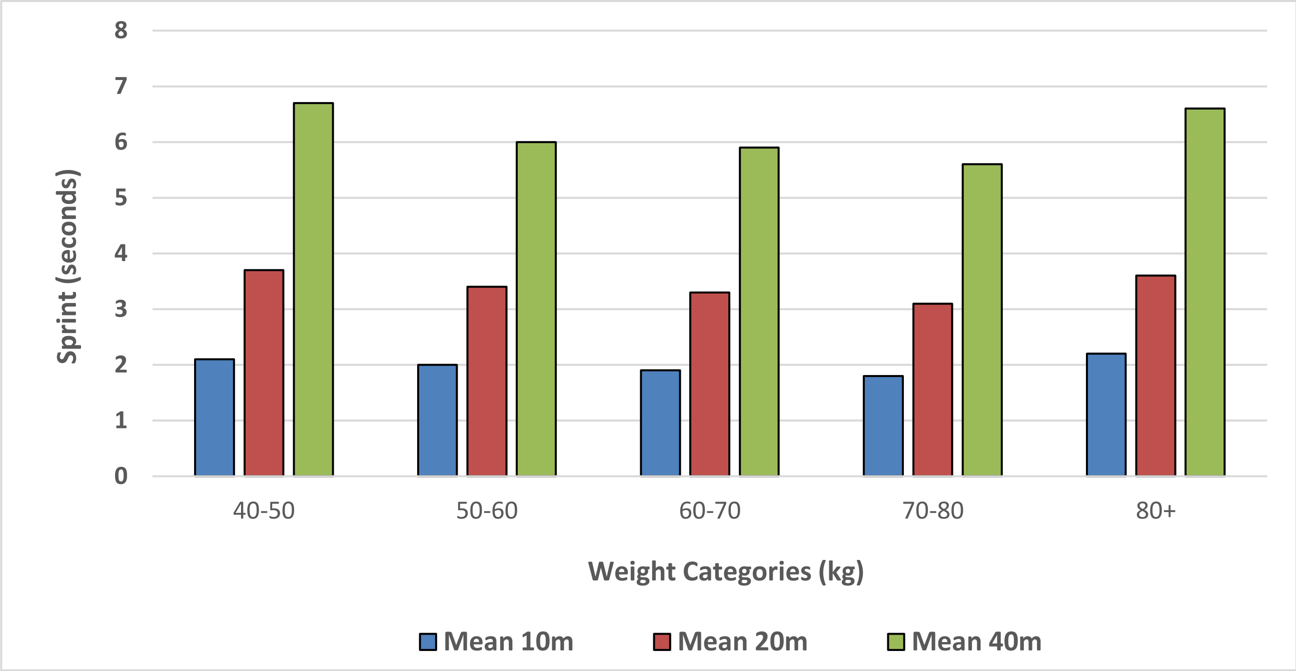


Figure 19. Bar chart of 10m, 20m, 40m sprint results by weight category (n = 90) ($p < 0.05$).

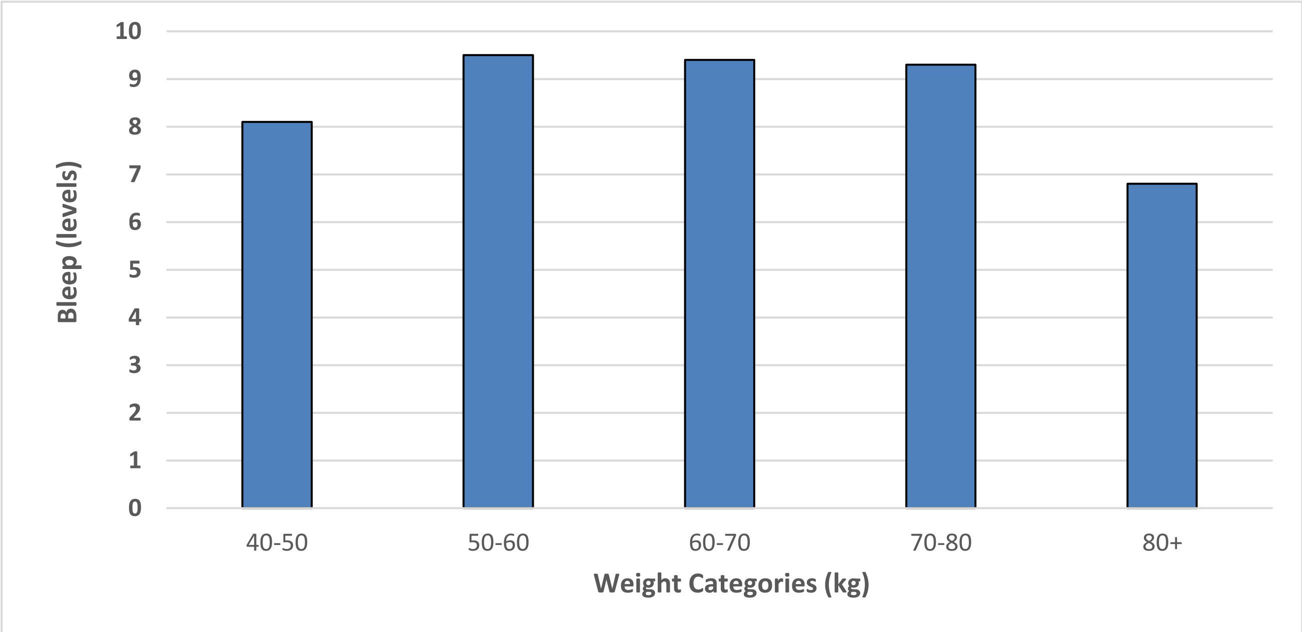


Figure 20. Bar chart of bleep test levels by weight category (n = 90) ($p < 0.05$).

4.2.5. CORRELATIONS BETWEEN POSTURE AND PERFORMANCE MEASURES

Table 5 - The correlation between the 10M, 20M, 40M, bleep test and total posture result within the HPC group

	10m	**20m**	**40m**	**Bleep**	**Total Posture**
10m	1.0000				
20m	0.8595*	1.0000			
40m	0.8635*	0.7193*	1.0000		
Bleep Test	0.4419	0.3569	0.5265*	1.0000	
Total Posture	-0.2345	-0.2973	-0.2699	0.2080	1.0000

* Statistically significant ($p < 0.05$).

Table 5 illustrates very strong positive correlations between the 10m sprint test results with the 20m and 40m sprint test results ($r = 0.86$, $r = 0.86$ respectively) ($p < 0.05$). Furthermore, there was a strong positive correlation between the 20m sprint test results and the 40m sprint test results ($r = 0.72$) ($p < 0.05$). A moderate positive correlation was observed between the bleep test results and 40m sprint test results ($r = 0.53$) ($p < 0.05$). A weak negative correlation was observed between total posture results and 10m, 20m and 40m sprint test results ($r = -0.23$, $r = -0.30$, $r = -0.27$ respectively) ($p < 0.05$). Furthermore, a weak positive correlation was observed between total posture results and bleep test results ($r = 0.21$) ($p < 0.05$).

Table 6: The correlation between the 10M, 20M, 40M, bleep test and total posture result within the private high school group

	10m	**20m**	**40m**	**Bleep**	**Total Posture**
10m	1.0000				
20m	0.8522*	1.0000			
40m	0.8056*	0.9585*	1.0000		
Bleep Test	-0.4691*	-0.5684*	-0.6000*	1.0000	
Total Posture	-0.2447	-0.3717*	-0.4920*	0.3698*	1.0000

* Statistically significant ($p < 0.05$).

Table 6 illustrates very strong positive correlations between the 10m sprint test results with the 20m and 40m sprint test results ($r = 0.85$, $r = 0.81$, respectively) ($p < 0.05$). Furthermore, there was a very strong positive correlation between the 20m sprint test results and the 40m sprint test results ($r = 0.96$) ($p < 0.05$). Moderate negative correlations were observed between the bleep test and 10m and 20m sprint test results ($r = -0.47$, $r = -0.57$, respectively) ($p < 0.05$). A strong negative correlation was observed between the bleep test results and 40m sprint test results ($r = -0.60$) ($p < 0.05$). A weak negative correlation was observed between total posture results and 20m sprint test results ($r = -0.37$) ($p < 0.05$). A moderate negative correlation was observed between total posture results and the 40m sprint test results ($r = -0.49$) ($p < 0.05$). Furthermore, a weak positive correlation was observed between total posture results and bleep test results ($r = 0.37$) ($p < 0.05$).

Table 7 - The correlations between the 10m, 20m, 40m, bleep test and total posture result within both participant groups combined

	10m	**20m**	**40m**	**Bleep**	**Total Posture**
10m	1.0000				
20m	0.8812*	1.0000			
40m	0.8524*	0.9489*	1.0000		
Bleep Test	-0.4644*	-0.5352*	-0.5688*	1.0000	
Total Posture	-0.3599*	-0.4725*	-0.5387*	0.4343*	1.0000

* Statistically significant ($p < 0.05$).

Table 7 illustrates very strong positive correlations between the 10m sprint test results with the 20m and 40m sprint test results (r = 0.88, r = 0.85, respectively) ($p < 0.05$). Furthermore, there was a very strong positive correlation between the 20m sprint test results and the 40m sprint test results (r = 0.95) ($p < 0.05$). Moderate negative correlations were observed between the bleep test results and all 10m, 20m and 40m sprint test results (r = -0.46, r = -0.54, r = -0.57, respectively) ($p < 0.05$). A weak negative correlation was observed between the total posture results and the 10m sprint test results (r = -0.36) ($p < 0.05$). Moderate negative correlations were observed between the total posture results and the 20m and 40m sprint test results (r = -0.47, -0.54, respectively) ($p < 0.05$). Furthermore, a moderate positive correlation was observed between total posture results and bleep test results (r = 0.43) ($p < 0.05$).

4.2.6. DIFFERENCES IN POSTURAL ASPECTS

Table 8 - Postural differences between participant groups (HPC and private high school)

Postural aspect	Chi-squared with ties $\chi 2(2)$	Probability (p)
Knee interspace	10.572 with 1 d.f.	0.0011*
Shoulder symmetry	2.679 with 1 d.f.	0.1017
Knee hyperextension/flexion	3.300 with 1 d.f.	0.0693
Lordosis	0.599 with 1 d.f.	0.4388
Kyphosis	1.584 with 1 d.f.	0.2081
Round shoulders	5.234 with 1 d.f.	0.0222*
Abducted scapulae	0.530 with 1 d.f.	0.4666
Forward head	0.679 with 1 d.f.	0.4100
Pelvic tilt	3.762 with 1 d.f.	0.0524*
Ankle posture	3.538 with 1 d.f.	0.0600
Scoliosis	2.276 with 1 d.f.	0.1314

* Statistically significant ($p < 0.05$).

According to Table 8, the Kruskal-Wallis H test showed that there was a significant difference in postural scores for knee interspace ($\chi 2(2) = 10.57$), round shoulders ($\chi 2(2) = 5.23$) and pelvic tilt ($\chi 2(2) = 3.76$) between the HPC and private high school groups ($p < 0.05$). Differences in various postural aspects may provide evidence that factors such as specificity of training, frequency of training, specialised strength and conditioning and restriction of sedentary behaviour may contribute to the postural differences between the groups.

4.2.7. DIFFERENCES BETWEEN ATHLETE TYPE

Table 9 - Postural differences between athlete types (HPC speed, HPC endurance and private high school)

Postural aspect	**Chi-squared with ties χ2(2)**	**Probability (p)**
Knee interspace	11.147 with 2 d.f.	0.0038*
Shoulder symmetry	3.395 with 2 d.f.	0.1831
Knee hyperextension/flexion	3.600 with 2 d.f.	0.1653
Lordosis	0.600 with 2 d.f.	0.7408
Kyphosis	3.120 with 2 d.f.	0.2101
Round shoulders	5.972 with 2 d.f.	0.0505*
Abducted scapulae	2.018 with 2 d.f.	0.3646
Forward head	2.225 with 2 d.f.	0.3288
Pelvic tilt	4.324 with 2 d.f.	0.1151
Ankle posture	3.897 with 2 d.f.	0.1425
Scoliosis	3.793 with 2 d.f.	0.1501

* Statistically significant ($p < 0.05$).

According to Table 9, the Kruskal-Wallis H test showed that there was a significant difference in postural scores for knee interspace and round shoulders between the HPC sprint, HPC endurance and private high school groups ($\chi2(2) = 11.15$, $\chi2(2) = 5.97$, respectively) ($p < 0.05$).

4.2.8. DIFFERENCES BETWEEN WEIGHT CATEGORY

Table 10 - Postural differences according to weight categories

Postural aspect	Chi-squared with ties $\chi2(2)$	Probability (p)
Knee interspace	9.241 with 4 d.f.	0.0553
Shoulder symmetry	3.808 with 4 d.f.	0.4326
Knee hyperextension/flexion	7.483 with 4 d.f.	0.1125
Lordosis	2.927 with 4 d.f.	0.5701
Kyphosis	2.879 with 4 d.f.	0.5782
Round shoulders	8.099 with 4 d.f.	0.0880
Abducted scapulae	15.069 with 4 d.f.	0.0046*
Forward head	7.676 with 4 d.f.	0.1042
Pelvic tilt	2.745 with 4 d.f.	0.6013
Ankle posture	5.998 with 4 d.f.	0.1993
Scoliosis	9.025 with 4 d.f.	0.0605

* Statistically significant ($p < 0.05$).

According to Table 10, the Kruskal-Wallis H test showed that there was a significant difference in postural scores for abducted scapulae between the various weight categories ($\chi2(2) = 15.07$) ($p < 0.05$).

4.3. DISCUSSION

THE RELATIONSHIP BETWEEN POSTURE AND RUNNING PERFORMANCE

The 10m, 20m, 40m sprint test results were superior for the HPC group (1.81s ± 0.12, 3.02s ± 0.23, 5.39s ± 0.31, respectively) in comparison to the private high school group (2.07s ± 0.27, 3.50s ± 0.34, 6.35s ± 0.62, respectively) ($p < 0.05$). The bleep test results (mean ± SD) were also superior for the HPC group (10.59 ± 1.88) in comparison to the private high school group (8.26 ± 1.94) ($p < 0.05$). The private high school participants are encouraged to participate in at least three different sports at school, and therefore, incorporate cross training into their training schedules. According to the results from Foster et al., a participant group that incorporated cross training had significantly less improvements in running performance than the direct training participant group.[120] This can be related to the findings of this study, that the HPC participant's primary training focus is on direct training, which can be related to the superior running speed and endurance results in comparison to the private high school participants, who are involved in a variety of sports and activities simultaneously. It was stated that: "sport-specific training is defined as exercise regimes that involve technical and/or tactical tasks similar to those of the athletes' chosen sport".[121] Several researchers identified prominent increases in the highest point of oxygen consumption (VO_2 peak), resulting from sport-specific training programs in elite junior athletes.[122-124] It is also important to understand that the HPC participants must have significant sporting talents to be part of the HPC school. This ensures that they are proficient in a specific sport, such as sprint running or endurance running.

The 10m, 20m and 40m sprint results (mean ± SD) were superior for the HPC sprint group (1.73s ± 0.09; 2.88s ± 0.22; 5.18s ± 0.20) in comparison to the HPC endurance group (1.88s ± 0.11; 3.16s ± 0.15; 5.60s ± 0.25) and private high school group (2.07s ± 0.27; 3.50s ± 0.34; 6.35s ± 0.62) ($p < 0.05$). These results were to be expected due to the HPC sprint group already participating at a national and/or international level of performance, with sprinting being their chosen sporting focus. Furthermore, specific training procedures and methods were put in place for the HPC sprint group to try increase sprint performances. This can be related to the results of Kotzamanidis et al. who provided evidence that a resistance training program in conjunction with a running-velocity training program can promote improvements in strength and running speed.[125] Various researchers provided evidence that running velocity can be improved by several training interventions, “such as sprint training without external resistance, towing, overspeed”,[126] and “specific plyometric (speed bound) exercises”.[127]

The bleep test results (mean ± SD) were superior for the HPC endurance group (11.90 ± 1.53) in comparison to the HPC sprint group (9.29 ± 1.17) and private high school group (8.26 ± 1.94) ($p < 0.05$). These results were to be expected due to the HPC endurance athletes already participating at a national and/or international level of performance. The intensity, duration and frequency of training sessions are far higher for the HPC endurance athletes in comparison to the private high school. Furthermore, the HPC endurance athletes are used to training sessions involving bleep tests or similar exercises directed at improving the aerobic endurance of the athletes. Tomlin and Wenger explained that superior aerobic fitness levels provides the ability for improved recovery, which contributes to suspending the onset of fatigue, which ultimately, gives the athlete the ability to participate in sustained high-intensity exercise.[128] Baquet et al. found that “aerobic physical training of 3-4 sessions per week for 8-12 weeks has been shown to increase VO_2 peak over and above the normal increase attributable to age and maturation by around eight to ten percent”.[129] This was further clarified that the rise in VO_2 max was primarily caused by an increase in maximal stroke volume, as a result of aerobic training programs.[130]

For sprint performance correlations, a negative correlation between sprint test results and total posture results meant that an improved sprinting performance was associated with better posture results. For endurance performance correlations, a positive correlation between bleep test results and total posture results meant that an improved endurance performance was associated with better posture results. When both participant groups were combined, the researcher identified very strong positive correlations between the 10m sprint test results with the 20m and 40m sprint test results (r = 0.88, r = 0.85, respectively) ($p < 0.05$). Furthermore, there was a very strong positive correlation between the 20m sprint test results and the 40m sprint test results (r = 0.95) ($p < 0.05$). These results were expected. Moderate negative correlations were observed between the bleep test results and all 10m, 20m and 40m sprint test results (r = -0.46, r = -0.54, r = -0.57, respectively) ($p < 0.05$). In agreeance with the results of this research study, it was previously found that sprint speed results may be related to bleep test results and therefore, endurance running performances.[131] A weak negative correlation was observed between the total posture results and the 10m sprint test results (r = -0.36) ($p < 0.05$). Furthermore, moderate negative correlations were observed between the total posture results and the 20m and 40m sprint test results (r = -0.47, -0.54, respectively) ($p < 0.05$). Sayers and Young et al. explained that good sprint running performances are built on a solid muscular balance structure.[66-67] According to Sayers and Young et al., an upright posture is an important component for sprinters. It was further explained that while sprinting, a forward lean provides the body with the essential position to initiate the pushing leg drive action which is crucial for improving speed.[66-67] Singer and Dip explained that the overall mechanics of running is affected as a result of muscular imbalances and compromised joint mechanics.[25] Phasic muscles are responsible for the forward movement of the runner, while the postural muscles to maintain muscular balance and control.[26] These findings may provide evidence that standing posture may be related to sprint performances, due to the use of both postural muscles and phasic muscles while running. A moderate positive correlation was observed between total posture results and bleep test results (r = 0.43) ($p < 0.05$). This finding can be supported by various researchers; A strong foundation of muscular balance including a stable core is vital for middle and long-distance runners.[26] According to the research of Morton and Callister, strong relationships existed between postural abnormalities and ETAP, which may lead to a reduction in aerobic endurance performance standards.[49] Watson explained that there is an inevitable relationship between posture and running economy, and further elucidated that postural alignment issues may cause a reduction in mechanical efficiency, thus decreasing performance levels in aerobic running.[34] Upright posture has been recognized to improve the economy of running by decreasing the amount of muscle activation which is essential for middle and long-distance running.[5] As previously mentioned, Fredericson and Moore clarified the benefits of attaining a positive muscular balance for a good posture, by stating that "when the system works efficiently, the result is appropriate distribution of forces; optimal control and efficiency of movement; adequate absorption of ground-impact forces; and an absence of excessive compressive, translation, or shearing forces on the joints of the kinetic chain".[26] According to a research conducted by the American Medical Athletic Association (AMAA), numerous athletes ignore the "anatomical anatomy and kinesiology of running, and with it, the physiology and biomechanics of exercise".[132] It was further explained that "posture can play a crucial role in improving athletic performance, as well as in alleviating aches and pains and avoiding injury".[132]

The HPC group had very strong positive correlations between the 10m sprint test results with the 20m and 40m sprint test results ($r = 0.86$, $r = 0.86$ respectively) ($p < 0.05$). Furthermore, there was a strong positive correlation between the 20m sprint test results and the 40m sprint test results ($r = 0.72$) ($p < 0.05$). These results were expected. A moderate positive correlation was observed between the bleep test results and 40m sprint test results ($r = 0.53$) ($p < 0.05$). This correlation indicates that superior bleep test score may result in slower sprint times. This may be caused by the specificity of training conducted by the HPC athletes, which is based around the athletic event of each athlete.

Similar results were noted in the private high school participants. The private high school group had very strong positive correlations between the 10m sprint test results with the 20m and 40m sprint test results ($r = 0.85$, $r = 0.81$, respectively) ($p < 0.05$). Furthermore, there was a very strong positive correlation between the 20m sprint test results and the 40m sprint test results ($r = 0.96$) ($p < 0.05$). These results were expected. Moderate negative correlations were observed between the bleep test and 10m and 20m sprint test results ($r = -0.47$, $r = -0.57$, respectively) ($p < 0.05$). Contrary to the HPC group, a strong negative correlation was observed between the bleep test results and 40m sprint test results for the private high school group ($r = -0.60$) ($p < 0.05$). This can be related to the research of Pyne et al. who assessed the correlation between repeated sprint ability and sprint speed.[131] Results were conclusive that repeated sprint ability using a 6x30-m distance was closely related to sprint speed.[131] A weak negative correlation was observed between total posture results and 20m sprint test results ($r = -0.37$) ($p < 0.05$). Furthermore, a moderate negative correlation was observed between total posture results and the 40m sprint test results ($r = -0.49$) ($p < 0.05$). These findings can be supported by the finding of Sayers and Young et al. who said that posture is a vital component of sprint running performances, due to an upright stance combined with a forward lean to promote a powerful leg drive action.[66-67] A weak positive correlation was observed between total posture results and bleep test results ($r = 0.37$) ($p < 0.05$).

POSTURAL DIFFERENCES BETWEEN COMPETITIVE AND NON-COMPETITIVE ATHLETES

The total posture scores (mean ± SD) of the HPC group (48.20 ± 4.09) was higher than the private high school group (44.83 ± 4.42) ($p < 0.05$). It was highlighted that "children with excellent posture spent significantly more time per week doing organized sport than children with poor posture".[112] This can be related to the training regimes in the participant groups; the HPC athletes had significantly higher training frequencies and durations in comparison to the private high school group. Furthermore, the potential for problematic sedentary lifestyle patterns are far more restricted for the HPC group due to strict daily routines and less free time due to intense training schedules. This can be related to the research of Janda who clarified that specific sedentary lifestyle patterns are often the cause of postural imbalances over time.[23]

The total posture results (mean ± SD) were superior for the HPC sprint group (49.13 ± 3.96) in comparison to the HPC endurance group (47.27 ± 4.13) and private high school group (44.83 ± 4.42) ($p < 0.05$). As previously mentioned, better postures are common in children who conduct regular weekly physical activities.[23] This can be the reason why the posture results of the HPC sprint and HPC endurance athlete types were superior in relation to the private high school posture results. Horak identified morphology as one of the biomechanical factors affecting standing posture.[133] The finding indicates that somatotype has an impact on various components of physical performance.[134] Specifically, mesomorphy may have a significant positive influence on sprint running gains, and the ectomorphic component may be positively associated with aerobic capacity gains.[134] The results from Kratěnová et al. quantified that body masses may be directly related to postural scores, with higher body masses resulting in higher postural scores.[112] Although this study did not have sufficient evidence of scoliotic postures, Kratěnová et al. discovered that "there was a lower occurrence of X-ray confirmed scoliosis in children with higher body weight".[112] Furthermore, "a higher fat tissue layer can hide existing skeletal problems and may also contribute to the stability of the spine".[112] This may explain why the HPC sprint group with higher body masses had superior postural scores in comparison to the HPC endurance group.

There was a significant difference in postural scores for knee interspace between the HPC and private high school groups ($\chi2(2) = 10.57$) ($p < 0.05$). The knee interspace results were superior for the HPC group in comparison to the private high school group. This may have been achieved by effective strength and conditioning programs conducted by the HPC group on a regular basis. Goldfuss et al. concluded that physically strong hamstring and quadricep muscles greatly decreased the chances of obtaining genu varum or genu valgus.[46] The strength and conditioning programs may target the aspects explained by Goldfuss et al., which may have decreased the chances of knee varum or valgus imbalances in the HPC participants. Muscles surrounding the knee structure play significant roles in ensuring knee stability and movement.[135] Substantial knee valgus and knee varus muscle strength is essential for executing various functional tasks like running, while maintaining stability in the knee joint.[135] These conclusions may provide evidence that good knee postures are needed for superior running performances. Furthermore, there was a significant difference in postural scores for knee interspace between the HPC sprint, HPC endurance and private high school ($\chi2(2) = 11.15$) ($p < 0.05$). The knee interspace results were inferior for the private high school group in comparison to the HPC endurance athletes. This can be further supported by Clement who explained that a mechanical compensation is often caused by genu varum or genu valgus, and therefore results in a decreased mechanical efficiency of movement.[44] A mechanical efficiency will severely inhibit the performances of the HPC endurance athletes due to the requirements of middle and long-distance running. Furthermore, the knee interspace results were inferior for the private high school group in comparison to the HPC sprint athletes. This may have been achieved by effective strength and conditioning programs conducted by the HPC sprint athletes on a regular basis. The strength and conditioning programs may have specific approaches to prevent knee varum or valgus imbalances. An example of this can be explained by Goldfuss et al. who concluded that “a structurally strong agonist-antagonist muscle combination of the hamstring and quadricep muscles, stabilized the knee and greatly reduced the chances of generating genu varum or genu valgus”.[46] These results may provide evidence that knee interspace may affect running speed and endurance performances.

There was a significant difference in postural scores for round shoulders between the HPC and private high school groups ($\chi2(2) = 5.23$) ($p < 0.05$). There is limited research based around shoulder posture alignment among adolescents.[99] In the research study conducted by Chansirinukor et al., an increase in mean shoulder posture angles (rounder shoulders) was related to backpack use.[108] This was further supported by various researchers; “many researchers have linked muscular imbalances in the shoulder to inefficient backpack use,[136] insufficient ergonomics in the seating arrangement at in schools,[137] psychosocial factors such as depression or stress,[138] and the practice of spending many hours seated with incorrect posture in school and in front of computers and televisions”.[139] The HPC group had superior shoulder posture results in comparison to the private high school group. Although both participant groups were at school for a similar duration every day, the duration of class time and sedentary “free time” is more prominent for the private high school group in comparison to the HPC group. This can be related to the research findings of Janda, who explained that the time spent doing sedentary tasks are often the cause of postural imbalances over time.[23] The HPC group had regular daily training sessions and less sedentary time which may decrease the chances of muscular imbalances and may contribute to superior shoulder postures. Furthermore, there was a significant difference in postural scores for round shoulders between the HPC sprint, HPC endurance and private high school ($\chi2(2) = 5.97$) ($p < 0.05$). Although rounded shoulder postures were found in all three athlete types, the private high school participates had far more incidences of this imbalance. In a study conducted by Ruivo et al. “58% of the adolescent participants displayed some degree of postural abnormality in the shoulder region”.[99] Cavagna et al. emphasized that an erect posture incorporates less muscle activation compared to a bent posture for a given movement, thus is beneficial for endurance activities.[59] This can be related to the findings of this research study, which found that the HPC endurance athletes had superior shoulder postures in relation to the private high school. Grasso et al. concluded from research testing, that when a participant adopted a bent posture, the mean EMG reading was increased by all muscles involved.[7] This may limit the available energy available for optimal sprint performance, which may explain why the HPC sprint athletes also had superior rounded shoulder posture scores in relation to the private high school. These results may provide evidence that shoulder posture may affect running speed and endurance performances. Shoulder posture imbalances can occur due to many various factors; therefore, it is vital to assess the daily lifestyle habits of individuals before conclusions can be made. “During the school years, the child's posture is subjected to many influences, and some alterations may appear due to improper postural habits”.[140] According to Rebelatto et al. “the way of carrying the backpack and the weight of school materials” have various effects on postural imbalances (shoulder imbalances) in students”.[141]

There was a significant difference in postural scores for pelvic tilt between the HPC and private high school groups ($\chi 2(2) = 3.76$) ($p < 0.05$). All pelvic imbalances were identified as anterior pelvic tilt, with no findings of posterior pelvic tilt within the participants. The HPC group had superior pelvic tilt results in comparison to the private high school group. This finding can supported by the research conducted by Young et al. who explained that immense forces are produced during the leg drive phase when running, and therefore require constant pelvic stability.[67] Sayers explained that the pelvic region is the connecting point between the legs and the upper body, and therefore requires stability and muscular balance to allow certain movement patterns to occur.[66] Due to the HPC athletes having superior pelvic stability and balance, one can assume that anterior pelvic tilt may affect running speed and endurance performances. This assumption is in agreeance with various authors who stated that: “anterior pelvic tilt is not only limited to decrements in performance standards but is also a major source of hamstring injuries”.[68-69] Deficiencies in core muscle organization can subsequently decreased the efficiency of movement and ultimately, cause compensatory movement patterns.[26,28] Kibler et al. described core stability as ‘‘the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities”.[142] The muscles surrounding the hip and pelvis are essential for reducing and transmitting the tremendous forces acting on the pelvic region during running, which is considered essential in sprint and endurance running.[143] Since core musculature is the support base for an individual’s posture, Fredericson and Moore hypothesized that “core musculature helps to stabilize the spine, pelvis, and kinetic chain during functional movements, which results is appropriate distribution of forces; optimal control and efficiency of movement; adequate absorption of ground-impact forces”.[26]

THE INFLUENCE OF BODY MASS (WEIGHT CATEGORIES) ON RUNNING PERFORMANCE AND POSTURE

The 70-80kg weight category was superior in the 10m (1.85s ± 0.13), 20m (3.13s ± 0.21) and 40m (5.60s ± 0.41) sprint test results (mean ± SD) in relation to the other weight categories ($p < 0.05$). The 70-80kg weight category was composed of participants who had larger muscle masses in relation to the lower weight categories. According to Sayers, larger muscles masses are essential to produce forceful leg drives which are vital components of sprint running performances.[66] This was further emphasized by Weyand and Davis who explained that sprinters are relatively large and muscular, and further hypothesized that the larger body masses of sprinters are directly related to the greater GRF produced, which is essential for superior sprint running performances.[111] This finding can be related to the research conducted by Thorstensson et al., who assessed the physical changes due to sprint related, strength exercises. It was concluded that increased thigh circumferences were considered beneficial to sprint performances.[144] The worst sprint results were attained by the 80+kg weight category 10m (2.22s ± 0.49), 20m (3.56s ± 0.34) and 40m (6.57s ± 0.61) ($p < 0.05$), which included participants who just made inclusion criteria with regards to high BF%. This means that some participants from this weight category had larger body masses, in conjunction with higher BF% in comparison to the other weight categories. In a study conducted by Sporis et al., results showed that higher BF% are inversely related to sprint performances in adolescents.[145] This was further supported by the research of Weyand et al. who concluded that Olympic sprint event runners maintained a mean BF% of (9.3 ± 1.8%).[95] These findings may explain why the 80+kg weigh category acquired the worst sprint results. Furthermore, having a body weight that was below 50kg also had negative impacts on sprint speed results. This finding can be related to findings of Castro-Piñero et al. who assessed the relationship between sprint performance and weight status.[146] It was concluded that underweight adolescents achieved inferior sprint results in comparison to the normal weight participants when participating in a 30m sprint test with a standing start.[146]

The 50-60-kilogram (kg) weight category was superior in the bleep test results (mean ± SD) (9.50 ± 2.56) in comparison to the 40-50kg (8.10 ± 1.47), 60-70kg (9.40 ± 2.01), 70-80kg (9.30 ± 1.77) and 80+kg (6.80 ± 2.17) weight categories ($p < 0.05$). This result was expected due to more than half of the HPC endurance athlete’s body masses falling in the 50-60kg weight category. The participants in the 50-60kg weight category had relatively low body masses in conjunction with low BF%. According to Weyand and Davis, endurance runners are evidently restricted in both body mass and muscle mass.[111] Various researchers explained that higher upper extremity masses were considered to be uneconomical in terms of endurance running, which lead to the reduction in upper extremity use and therefore a reduction in endurance running results.[147-149]

The total posture results (mean ± SD) were superior for the 70-80kg weight category (47.47 ± 3.20) in comparison to the 40-50kg (41.00 ± 3.52), 50-60kg (46.89 ± 5.71), 60-70kg (46.77 ± 3.84) and 80+kg (44.14 ± 3.63) weight categories ($p < 0.05$). As previously discussed, Kratěnová et al. found higher body masses to be beneficial in terms of postural scores.[112] This may explain why the 70-80kg weight category in this study had far superior postural scores in comparison to the 40-50kg weight category. Kratěnová et al. further emphasized that individuals who are considered underweight are more susceptible to poor postures.[112] This can be related to the posture results of the 40-50kg weight category, which attained the worst postural scores in comparison to the other weight categories. It is important to remember that there are inevitably other factors that may influence posture. “There are intrinsic and extrinsic factors, such as heredity, the environment or physical conditions in which the subject lives, socioeconomic level, emotional factors, and physiologic alterations due to human growth and development”.[109]

There was a significant difference in postural scores for abducted scapulae between the various weight categories ($\chi 2(2) = 15.07$) ($p < 0.05$). Abducted scapular postures were more frequent in individuals in the 40-50kg and 50-60kg weight categories. This can be related to the findings of Kratěnová et al. who discussed that individuals who are considered underweight are more susceptible to poor postures.[112] It was further emphasized that “higher fat tissue layer can hide existing skeletal problems”, which may promote higher incidences of abducted scapulae in the lower weight categories.[112] The 70-80kg weight category which mainly consisted of the HPC sprint athletes, had superior scapular posture scores in comparison to the other weight categories. This can be related to the findings of other researchers; “In first accelerated running, the arm-swing motion affects lower limb kinematics[62] and relates to the performance level of the sprinter in the 100-m dash[63] and the sprint time[150] of the athlete”. Winged scapular is extremely common during the childhood due to poor scapulothoracic fixation.[151-152] According to Tanaka and Farah: “shoulder protraction is mechanically associated with the scapular abduction; it can be also related to its lateral rotation and to the medial rotation of the shoulders, which occurs because of the predominant action of serratus anterior and major pectoral muscles over the rhomboid and trapezius muscles”.[153] These findings may provide evidence that muscle imbalances around the scapular are common in adolescents and children, and therefore require effective strategies to correct, so that positive growth and improved running performances can be achieved.

4.4. CONCLUSIONS

Chapter 4 listed all the research results which was further discussed so that conclusions could be made.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. INTRODUCTION

Chapter five briefly summarizes the research study completed by the researcher. Major findings will be discussed and general recommendations to future research papers will be covered. Final conclusions will be emphasized.

5.2. SUMMARY

Chapter one included all the background information of the research study, the purpose of the study conducted, the specific objectives that were followed by the researcher, the significance of the study, delimitations that occurred in the study and limitations overcome in the study. The two major objectives that the research study followed:

- To assess the postural assessment scores of eleven postural components, running endurance results from 20m multistage shuttle run tests and running speed results from 10m, 20m and 40m sprint tests within the two participant groups (private high-school and a high-performance running academy).
- To correlate the eleven postural assessment scores, running speed results from 10m, 20m and 40m sprint tests and running endurance results from 20m multistage shuttle run tests between the two participant groups (private high-school and a high-performance running academy.

Chapter 2 explained the theory behind the research topic which is described by various information sources, which was further related to the research project. This was achieved by a thorough literature review which explained the background information explained by various other researchers. Posture, Speed and endurance was thoroughly defined.

Chapter 3 describes the procedures used to gather and analyse the research data. All the aspects that played a role in data collection were explained. Study design, population and sampling, measurements and procedures, data analysis and ethical considerations

Chapter 4 examines all the research results, and then further discusses them so that conclusions could be made. Descriptive statistics for each test were explained and significant correlations were highlighted.

Chapter 5 is composed of a general summary of the research study, and recommendations for future research is explained.

5.3. CONCLUSIONS

From the results of this study, higher overall posture ratings (better posture) are correlated with better speed and aerobic endurance. It was concluded that the HPC athlete group achieved better sprint, endurance and postural results in comparison to the private high school group. It was further concluded that children should follow specific exercise programmes to maintain or improve posture. This will provide a solid base for physical development and will ensure a healthy muscular balance throughout the body. Teachers, coaches and sport scientists should be educated on the effects of poor posture and therefore, try promoting an effective posture during class and sport. Early postural identification is the key to ensuring positive posture in children. Early identification will allow for postural imbalances to be corrected before puberty and therefore, ensuring effective development. Furthermore, correcting postural imbalances in children will not only enhance self-esteem, but also promote a positive mindset which is essential for growth and development

5.4. RECOMMENDATIONS

Due to the research testing technique, acquiring female participants within the age category would be a difficult task due to ethical boundaries and consent. The effect of pre-exercise standing posture on running performance in adolescent females may yield different results in comparison to the findings of this study. Research methods can be adapted to incorporate female participants and thus, increase the pool of knowledge on the effect of standing posture on running performances. Further research can be conducted to assess whether postural promotion before puberty is beneficial to the development of the individual. This may limit the incidences of problematic postures and therefore may promote improved growth and development. Research focus can also be directed to the effect of posture on sporting career longevity. Identifying the relationship between static posture and the time span of a professional sporting career may be an insightful and significant finding. Assessing the relationship between standing posture and the emotional state of adolescents may also provide valuable results. This may provide evidence linking standing posture to self-esteem and self-worth.

REFERENCES

1. Watson AWS, Mac Donncha C. A reliable technique for the assessment of posture: Assessment criteria for aspects of posture. J Sports Med Phys Fitness. 2000;40(3):260-70.
2. Darwin C (1871) The Descent of Man, and Selection in Relation to Sex (John Murray, London); reprinted (1981) (Princeton Univ, Princeton).
3. Zollikofer CPE, Ponce de Leon MS, Lieberman DE, Guy F, Pilbeam D, Likius A, Mackaye HT, Vignaud P, Brunet M. Nature. Virtual cranial reconstruction of Sahelanthropus tchadensis. 2005;434:755–759.
4. Rodman PS, McHenry HM. Bioenergetics and the origin of hominid bipedalism. American Journal of Physical Anthropology. 1980 Jan;52(1):103-6.
5. Sockol MD, Raichlen DA, Pontzer H. Chimpanzee locomotor energetics and the origin of human bipedalism. Proceedings of the National Academy of Sciences. 2007 Jul 24;104(30):12265-9.
6. Kurbel S, Rapan S. Evolution of human posture and bipedal locomotion within a provisional time frame of harsh climate changes. Periodicum biologorum. 2015 Mar 31;117(1):11-5.
7. Grasso R, Zago M, Lacquaniti F. Interactions between posture and locomotion: motor patterns in humans walking with bent posture versus erect posture. J. Neurophysiol. 2000;83:288-300.
8. Crompton RH, Weijie LY, Günther M, Savage R. The mechanical effectiveness of erect and “bent-hip, bent-knee” bipedal walking inAustralopithecus afarensis. Journal of Human Evolution. 1998 Jul 1;35(1):55-74.
9. Spoor F, Wood B, Zonneveld F. Implications of early hominid labyrinthine morphology for evolution of human bipedal locomotion. Nature. 1994 Jun;369(6482):645.
10. Skoyles JR. Human balance, the evolution of bipedalism and dysequilibrium syndrome. Medical hypotheses. 2006 Jan 1;66(6):1060-8.
11. Bramble DM, Lieberman DE. Endurance running and the evolution of Homo. Nature. 2004 Nov;432(7015):345.
12. Schmid P. Functional interpretation of the Laetoli footprints. In: Meldrum DJ, Hilton CE, editors. Biped to Strider: The emergence of modern human walking,

running, and resource transport. New York: Kluwer Academic/Plenum; 2004. p. 49–62.
13. Poliakoff MB. Combat sports in the ancient world: Competition, violence, and culture. Yale University Press; 1987.
14. Finley MI, Pleket HW. The Olympic Games: the first thousand years. Courier Corporation; 2012 May 24. Page 6.
15. Hughes M. A review of patterns of play in squash. Sports Science. 1986:363-8.
16. Hughes MD, Bartlett RM. The use of performance indicators in performance analysis. Journal of sports sciences. 2002 Jan 1;20(10):739-54.
17. Yeadon MR, Challis JH. Future directions for performance related research in sports biomechanics. Sports Council; 1992.
18. Breivik G, Hanstad DV, Loland S. Attitudes towards use of performance-enhancing substances and body modification techniques. A comparison between elite athletes and the general population. Sport in society. 2009 Aug 1;12(6):737-54.
19. Steele E, BialocerkowskI A, Grimmer K. The postural effects of load carriage on young people; a systematic review. BMC Musculoskelet Disord. 2003;4:12.
20. Abd-Elkader SF, EL-Bab MF. The Back Rotation Resulted from the Wrong Body Conditions of Long-Distance Competitors and its Impact on Some Physiological and Morphological Variables and Recording Level. World. 2010;3(4):329-36.
21. Hansraj KK. Assessment of stresses in the cervical spine caused by posture and position of the head. Surg Technol Int. 2014 Nov;25(25):277-9.
22. Watson AWS. Physical fitness and athletic performance. 2nd edition. London: Longman; 1995;63-5
23. Janda V. Muscles as a pathologic factor in back pain. In: Buswell J, Gibson-Smith M (eds), Proceedings of the International Federation of Manipulative Therapists, Christchurch. New Zealand. 1982;1-24.
24. Mannheimer JS, Rosenthal RM. Acute and chronic postural abnormalities as related to craniofacial pain and temporomandibular disorders. Dent Clin North Am. 1991;35:185-208.
25. Singer KP, Dip PE. A New Musculoskeletal Assessment in a Student Population. The J Orthop Sports Phys Ther. 1986;8(1):34-41.

26. Fredericson M, Moore T. Muscular Balance, Core Stability, and Injury Prevention for Middle and Long-Distance Runners. Phys Med Rehabil Clin N Am 16. 2005;669-89.
27. Kendall F, McCreary E, Provance P. Muscle testing & function. Baltimore: Williams and Wilkins. 1993;50:685-90.
28. Akuthota V, Ferreiro A, Moore T, and Fredericson M. Core stability exercise principles. Curr. Sports Med. Rep. 2008;7(1):39-44.
29. Bloomfield J, Ackland TR, Elliot BC. Applied Biomechanics and Anatomy in Sport Melbourne: Blackwell Scientific Publications. 1994;40-92.
30. Karlin LI. Injury to the hip and pelvis in the skeletally immature athlete. In The Lower Extremity and Spine in Sports Medicine. (Ed): Nicholas JA, Hershman EB. St Louis: Mosby; 1986;1292-1332.
31. Wojtys EM. Sport injuries in the immature athlete. Orthop Clin North Am. 1987;18:689-694.
32. McEvoy M, Grimmer K. Reliability of upright posture measurements in primary school children Maureen. BMC Musculoskeletal Disorders. 2005;6:35.
33. Lowman C. Faulty posture in relation to performance. J Sport Health Sci. 1958;29:14-5.
34. Watson AWS. Sports injuries in footballers related to defects of posture and body mechanics. J Sports Med Phys Fitness. 1995;35:289-94.
35. Janda V. Muscles and motor control in low back pain. Assessment and management. In: Twomey LT (Ed.) Physical therapy of the low back. Churchill Livingstone: New York. 1987;253-78.
36. Janda V. The technique of therapy of postural and phasic muscles. New Zealand Manip Ther Assoc Tech Newsletter. 1977;2:1-3.
37. Janda V: On the concept of postural muscles and posture in man. Aust J Physiother. 1983;29:83-85.
38. Chang YW, Hung W, Wu H, Chiu YC, Hsu HC. Measurements of foot arch in standing, level walking, vertical jump and sprint start. International Journal of Sport and Exercise Science. 2010;2(2):35-42.
39. Williams DS, III, McClay IS, Hamill J. Arch structure and injury patterns in runners. Clin Biomech. 2001;16:341-7.

40. Cubucku S, Alimoglu MK, Balci N, Beyazova M. Plantar arch type and strength profile of the majory ankle muscle groups: a morphometric-isokinetic study. Isokinet Exerc Sci. 2005;13:217-22.
41. Frederick EC, Clarke TC, Hansen JL, Cooper LB. The effects of shoe cushioning on the oxygen demands of running. In: Biomechanical Aspects of Sports Shoes and Playing Surfaces (eds B. Nigg & B. Kerr). 1983;107-14.
42. Johnston CAM, Taunton JE, Lloyd-Smith DR, McKenzie DC. Preventing running injuries. Practical approach for family doctors. Can Fam Physician. 2003;49:1101-9.
43. Nigg BM, Nurse MA, Stefanyshyn DJ. Shoe inserts and orthotics for sport and physical activities. Med Sci Sports Exerc. 1999;3:S421-8.
44. Clement DB. The practical application of exercise training principles in family medicine. Can Fam Physician. 1982;28:929-32.
45. Dierks TA, Manal KT, Hamill J, Davis IS. Proximal and Distal Influences on Hip and Knee Kinematics in Runners with Patellofemoral Pain during a Prolonged Run. J Orthop Sports Phys Ther. 2008;38(8):448-56.
46. Goldfuss AJ, Morehouse CA, Leveau BF. Effect of muscular tension on knee stability. Med. Sci. Sports. 1973;5:267-71.
47. Mcmahon TA, Valiant G, Frederick EC. Groucho running. J Appl Physiol. 1987;62(6):2326-37.
48. Biewener A. Biomechanics of mammalian terrestrial locomotion. Science. 1990;250:1097-1103.
49. Morton DP, Callister R. Influence of posture and body type on the experience of exercise-related transient abdominal pain. J Sci Med Sport. 2010;13:485-48.
50. Lichota M, Plandowska M, Mil P. The shape of anterior-posterior curvatures of the spine in athletes practising selected sports. Pol. J. Sport Tourism. 2011;18:112-6.
51. Giles LGF, Taylor JR. Low back pain associated with leg length inequality. Spine. 1981;6:510-21.
52. Grieve GP. Treating backache-a topical comment. Physiotherapy. 1983;69:316.
53. Taylor JR. Scoliosis and growth patterns of asymmetry in normal vertebral growth. Acta Orthop Scand. 1983;54:596-602.

54. Di-Rocco PJ, Vaccaro P. Cardiopilmonary functioning in adolescent patients with mild idiopathic scoliosis. Arch Phys Med Rehabil. 1988;69:198-201.
55. Chen PQ, Wang JL, Tsuang YH, Liao TL, Huang PI, Hang YS. The postural control and gait pattern of idiopathic scoliosis in adolescents. Clin Biomech. 1998;13(1):52-8.
56. Cole AK, McGrath ML, Harrington SE, Padua DA, Rucinski TJ, Prentice WE. Scapular bracing and alteration of posture and muscle activity in overhead athletes with poor posture. Journal of athletic training. 2013 Jan;48(1):12-24.
57. Lewis JS, Green A, Wright C. Subacromial impingement syndrome: the role of posture and muscle imbalance. J Shoulder Elbow Surg. 2005a;14(4):385–392.
58. Lewis JS, Wright C, Green A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. J Orthop Sports Phys Ther. 2005b;35(2):72–87.
59. Cavagna G, Heglund N, Taylor C. Mechanical work in terrestrial locomotion: two basic mechanisms for minimizing energy expenditure. Am. J. Physiol. 1977;233,243-61.
60. Peterson DE, Blankenship KR, Robb JB, Walker MJ, Bryan JM, Stetts DM, et al. Investigation of the validity and reliability of four objective techniques for measuring forward shoulder posture. J Orthop Sports Phys Ther. 1997;25(1):34-42.
61. Culham E, Peat M. Spinal and shoulder complex posture: Measurement using the 3Space Isotrak. Clin Rehabil. 1993;309-18.
62. Lockie RG, Callaghan SJ, Jeffriess MD. Acceleration kinematics in cricketers: implications for performance in the field. J Sport Sci Med. 2014;13(1):128–36.
63. Slawinski J, Bonnefoy A, Leveque JM, Ontanon G, Riquet A, Dumas R, et al. Kinematic and kinetic comparisons of elite and well-trained sprinters during sprint start. J Strength Cond Res. 2010a;24(4):896–905.
64. Otsuka M, Ito T, Honjo T, Isaka T. Scapula behavior associates with fast sprinting in first accelerated running. SpringerPlus. 2016;5:682.
65. Jull G, Janda V. Muscles and motor control in low back pain: Assessment and management in: Physical Therapy of the Low Back. 1987;253-78.
66. Sayers M. Running techniques for running rugby. New Zealand Coach. 1999;7:20-3.

67. Young W, Benton D, John-Pryor M. Resistance training for short sprints and maximum-speed sprints. Strength Cond J. 2001;23(2):7.
68. Geraci MC Jr. Overuse injuries of the hip and pelvis. J Back Musculoskelet Rehabil. 1996;1;6(1):5-19.
69. Klein KK, Roberts CA. Mechanical problems of marathoners and joggers: Cause and solution. Am Correct Ther J. 1976;30:187-91.
70. Slocum DB, James SL. Biomechanics of running. JAMA. 1968; 205:721-28.
71. Vogt L, Pfeifer K, Banzer W. Neuromuscular control of walking with chronic low-back pain. Man Ther. 2003;8(1):21-8.
72. Jones AM, Carter H. The effect of endurance training on parameters of aerobic fitness. Sports Med. 2000;29:373-86.
73. Howley ET, Bassett DR, Welch HG. Criteria for maximal oxygen uptake: review and commentary. Medicine and science in sports and exercise. 1995 Sep 1;27(9):1292-301.
74. Rowell LB. Human cardiovascular adjustments to exercise and thermal stress. Physiological reviews. 1974 Jan;54(1):75-159.
75. Hill AV, Lupton H. Muscular exercise, lactic acid, and the supply and utilization of oxygen. QJM: Quarterly Journal of Medicine. 1923 Jan;1(62):135-71.
76. Baechle TR, Earle RW, Wathan D. Resistance Training. In: Essentials of Strength Training and Conditioning. Ed: Baechle TR, Earle RW. 3rd edition. Champaign, IL: Human Kinetic; 2008;396.
77. Ray CA, Cureton KJ. Interactive effects of body posture and exercise training on maximal oxygen uptake. J. Appl. Physiol. 1991;71(2):596-600.
78. Numella A, Keranen T, Mikkelsson LO. Factors Related to Top Running Speed and Economy. Int J Sports Med. 2007;28(8):655-61.
79. Kesten S, Garfinkel SK, Wright T, Rebuck AS. Impaired exercise capacity in adults with moderate scoliosis. CHEST Journal. 1991;99(3):663-6.
80. Lenke LG, White DK, Kemp JS, Bridwell KH, Blanke KM, Engsberg JR. Evaluation of ventilatory efficiency during exercise in patients with idiopathic scoliosis undergoing spinal fusion. Spine (Phila Pa 1976). 2002;27:2041-5.
81. Michand PA, Caudery M, Schutzy S. Assessment of physical activity with ape do motor and its relationship with VO among adolescents. in Switzerland, Soz Praventivmed. 2002;47:107-15.

82. Lamb DR. Basic principles for improving sport performance. Sports Sci Exch. 1995;8:1-5.
83. Saunders PU, Pyne DB, Telford RD, Hawley JA. Factors Affecting Running Economy in Trained Distance Runners. Sports Med. 2004;34(7):465-85.
84. Heise GD, Martin PE. Are variations in running economy in humans associated with ground reaction force characteristics? Eur J Appl Physiol. 2001;84:438-42.
85. Kaneko M, Ito A, Fuchimoto T, Shishikura Y, Toyooka J. Influence of running speed on the mechanical efficiency of sprinters and distance runners. In: Winter DA, Norman RW, Wells RP, Heyes KC, Patla AE (eds). Biomechanics IX-B. Champaign, IL, USA: Human Kinetics. 1985;307-12.
86. Dalleau G, Belli A, Bourdin M, Lacour J-R. The spring-mass model and the energy cost of treadmill running. Eur J Appl Physiol. 1998;77:257-63.
87. Gregor RJ, Kirkendall D. Performance efficiency of world class female marathon runners. In: Asmussen E, Jørgensen K (eds). Biomechanics VI-B. Baltimore, USA: University Park Press. 1978;40-5.
88. Paavolainen LM, Nummela AT, Rusko HK. Neuromuscular characteristics and muscle power as determinants of 5-km running performance. Med Sci Sports Exerc. 1999;31:124-30.
89. Williams KR, Cavanagh PR. Relationship between distance running mechanics, running economy, and performance. J Appl Physiol. 1987;63:1236-45.
90. Cavanagh PR, Williams KR. The effect of stride length variation on oxygen uptake during distance running. Med Sci Sports Exerc. 1982;14:30-3.
91. Reilly T, Bangsbo J, Franks A. Anthropometric and physiological predispositions for elite soccer. J Sport Sci. 2000;18(9):669-83.
92. Sayers M. Running techniques of field sport players. Sport Coach. 2000;23(1):26–7.
93. Luhtanen P, Komi PV. Mechanical factors influencing running speed. In: Asmussen E, Jørgensen K (eds). Biomechanics VI-B. Baltimore, USA: University Park Press. 1978;23-9.
94. Mero A, Komi PV. Forve, EMG, and elasticity-velocity relationships at submaximal and supramaximal running speeds in sprinters. Eur J Appl Physiol 1986;55:553-61.

95. Weyand PG, Sternlight DB, Bellizzi MJ, Wright S. Faster top running speeds are achieved with greater ground reaction forces not more rapid leg movements. J Appl Physiol. 2000;89:1991-99.
96. Kyröläinen H, Belli A, Komi PV. Biomechanical factors affecting running economy. Med Sci Sports Exerc. 2001;33:1330-1337.
97. Hunter JP, Marshall RN, McNair PJ. Relationships between ground reaction force impulse and kinematics of sprint-running acceleration. Journal of applied biomechanics. 2005 Feb;21(1):31-43.
98. Hinrichs RN, Cavanagh PR, Williams KR. Upper extremity function in running. 1: Centre of mass and propulsion considerations. Int. J. Sport Biomech. 1987;3:222-41.
99. Ruivo RM, Pezarat-Correia P, Carita AI. Intrarater and interrater reliability of photographic measurement of upper-body standing posture of adolescents. Journal of manipulative and physiological therapeutics. 2015 Jan 1;38(1):74-80.
100. Perry M, Smith A, Straker L, Coleman J, O'Sullivan P. Reliability of sagittal photographic spinal posture assessment in adolescents. Advances in Physiotherapy. 2008 Jan 1;10(2):66-75.
101. Weber P, Corrêa EC, Milanesi JM, Soares JC, Trevisan ME. Craniocervical posture: cephalometric and biophotogrammetric analysis. Brazilian Journal of Oral Sciences. 2016 Dec 12:416-21.
102. Raine S, Twomey LT. Posture of the head, shoulders and thoracic spine in comfortable erect standing. Aust J Physiother. 1994;40(1):25-32.
103. Beningfield S, Potgieter H, Nicol A, van As S, Bowie G, Hering E, Lätti E. Report on a new type of trauma full-body digital X-ray machine. Emerg Radiol. 2003;10:23-9.
104. Arnheim DD, Auxter D, Crowe WG. Principles and methods of adapted physical education and recreation. 3rd edition. St Louis: C V. Mosby Company. 1977
105. Johnson, Barry L & Nelson, Jack K. Practical measurements for evaluation in physical education, 4th ed, (Burgess Pub, Edina, MN). 1986
106. Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice. Lippincott Williams & Wilkins; 2007.
107. Cho CY: Survey of faulty postures and associated factors among Chinese adolescents. J Manipulative Physiol Ther, 2008, 31: 224–229 [PubMed]).

108. Chansirinukor W, Wilson D, Grimmer K, Dansie B. Effects of backpacks on students: measurement of cervical and shoulder posture. Australian Journal of physiotherapy. 2001 Jan 1;47(2):110-6.
109. Penha PJ, João SM, Casarotto RA, Amino CJ, Penteado DC. Postural assessment of girls between 7 and 10 years of age. Clinics. 2005 Feb;60(1):9-16.
110. Tattersall R, Walshaw MJ. Posture and cystic fibrosis. Journal of the royal society of medicine. 2003;96(Suppl 43):18.
111. Weyand PG, Davis JA. Running performance has a structural basis. J Exp Biol. 2005;208:2625-31.
112. Kratěnová J, ŽEjglicová K, Malý M, Filipová V. Prevalence and risk factors of poor posture in school children in the Czech Republic. Journal of School Health. 2007 Mar;77(3):131-7.
113. Grøholt EK, Stigum H, Nordhagen R, Köhler L. Recurrent pain in children, socio-economic factors and accumulation in families. European journal of epidemiology. 2003 Oct 1;18(10):965-75.
114. Brügger A. Kinesiological aspects of functional limitations during movement and posture. Rehabilitácia. 1993;26:136-44.
115. Filipová V, Kratenová J, Trestrová Z. National Program of Health—Grant Projects for the Support of Health 1994-2004. Prague, Czech Republic: Regional Public Health Authority and Institute of Health of the Middle Bohemian Region. 2005.
116. Plowman SA, Meredith MD. (Eds.). Fitnessgram/Activitygram Reference Guide (4th Edition). Dallas, TX: The Cooper Institute. 2013;3:7-9.
117. Robertson SM, Cullen KW, Baranowski J, Baranowski T, Hu S. Factors related to adiposity among children aged 3 to 7 years. Journal of the American Dietetic Association. 1999 Aug 1;99(8):938-43.
118. Leger LA, Lambert JA. maximal multistage 20-m shuttle run test to predict dot VO2 max. Eur J Appl Physiol Occup Physiol. 1982;49(1):1-2.
119. Rebekić A, Lončarić Z, Petrović S, Marić S. Pearson's or spearman's correlation coefficient-which one to use?. Poljoprivreda (Osijek). 2015 Jan 1;21(2):47-54.

120. Foster C, Hector LL, Welsh R, Schrager M, Green MA, Snyder AC. Effects of specific versus cross-training on running performance. European journal of applied physiology and occupational physiology. 1995 Jul 1;70(4):367-72.
121. Harrison CB, Gill ND, Kinugasa T, Kilding AE. Development of aerobic fitness in young team sport athletes. Sports Medicine. 2015 Jul 1;45(7):969-83.
122. Chamari K, Hachana Y, Kaouech F, Jeddi R, Moussa-Chamari I, Wisloff U. Endurance training and testing with the ball in young elite soccer players. Br J Sports Med. 2005;39(1):24–8.
123. Buchheit M, Laursen PB, Kuhnle J, Ruth D, Renaud C, Ahmaidi S. Game-based training in young elite handball players. Int J Sports Med. 2009;30(4):251–8.
124. Impellizzeri F, Marcora SM, Castagna C, Reilly T, Sassi A, Iaia FM, et al. Physiological and performance effects of generic versus specific aerobic training in soccer players. Int J Sports Med. 2006;27(6):483–92.
125. Kotzamanidis C, Chatzopoulos D, Michailidis C, Papaiakovou G, Patikas D. The effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players. The Journal of Strength & Conditioning Research. 2005 May 1;19(2):369-75.
126. Delecluse C. Influence of strength training on sprint running performance. Sports Medicine. 1997 Sep 1;24(3):147-56.
127. Rimmer E, Sleivert G. Effects of a plyometrics intervention program on sprint performance. The Journal of Strength & Conditioning Research. 2000 Aug 1;14(3):295-301.
128. Tomlin DL, Wenger HL. The relationship between aerobic fitness and recovery from high intensity exercise. Sports Med. 2001;31(1):1–11.
129. Baquet G, Van Praagh E, Berthoin S. Endurance training and aerobic fitness in young people. Sports Med. 2003;33(15): 1127–43.
130. Obert P, Mandigouts S, Nottin S, Vinet A, N'Guyen LD, Lecoq AM. Cardiovascular responses to endurance training in children: effect of gender. European journal of clinical investigation. 2003 Mar;33(3):199-208.
131. Pyne DB, Saunders PU, Montgomery PG, Hewitt AJ, Sheehan K. Relationships between repeated sprint testing, speed, and endurance. The Journal of Strength & Conditioning Research. 2008 Sep 1;22(5):1633-7.
132. AMAA Journal. 2004;17(1):8-10.

133. Horak FB. Clinical assessment of balance disorders. Gait & posture. 1997 Aug 1;6(1):76-84.
134. Marta CC, Marinho DA, Barbosa TM, Carneiro AL, Izquierdo M, Marques MC. Effects of body fat and dominant somatotype on explosive strength and aerobic capacity trainability in prepubescent children. The Journal of Strength & Conditioning Research. 2013 Dec 1;27(12):3233-44).
135. Zhang LQ, Xu D, Wang G, Hendrix RW. Muscle strength in knee varus and valgus. Medicine & Science in Sports & Exercise. 2001 Jul 1;33(7):1194-9
136. Ramprasad M, Alias J, Raghuveer AK. Effect of backpack weight on postural angles in preadolescent children. Indian pediatrics. 2010 Jul 1;47(7):575-80
137. Murphy S, Buckle P, Stubbs D. Classroom posture and self-reported back and neck pain in schoolchildren. Applied ergonomics. 2004 Mar 1;35(2):113-20
138. Prins Y, Crous L, Louw QA. A systematic review of posture and psychosocial factors as contributors to upper quadrant musculoskeletal pain in children and adolescents. Physiotherapy theory and practice. 2008 Jan 1;24(4):221-42
139. Brink Y, Crous LC, Louw QA, Grimmer-Somers K, Schreve K. The association between postural alignment and psychosocial factors to upper quadrant pain in high school students: A prospective study. Manual therapy. 2009 Dec 1;14(6):647-53
140. Casarotto RA, Liberti EA. Anthropometric data of pre-school children in the city of São Paulo. Physiotherapy and Research. 1994; 1 (1): 27-33
141. Rebelatto JR, Caldas MA, Vitta AD. Influence of transport of school material on the occurrence of postural deviations in students. Rev. bras. ortop. 1991 Dec; 26 (11/12): 403-10
142. Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports Med 2006; 36 (3): 189-98
143. Geraci MC, Brown W. Evidence-based treatment of hip and pelvic injuries in runners. Physical Medicine and Rehabilitation Clinics. 2005 Aug 1;16(3):711-47.
144. Thorstensson A, Sjödin B, Karlsson J. Enzyme activities and muscle strength after “sprint training” in man. Acta Physiologica Scandinavica. 1975 Jul;94(3):313-8.

145. Sporis G, Jukic I, Ostojic SM, Milanovic D. Fitness profiling in soccer: physical and physiologic characteristics of elite players. The Journal of Strength & Conditioning Research. 2009 Oct 1;23(7):1947-53.
146. Castro-Piñero J, González-Montesinos JL, Keating XD, Mora J, Sjöström M, Ruiz JR. Percentile Values for Running Sprint Field Tests in Children Ages 6-17 Years: Influence of Weight Status. Res Q Exerc Sport 2010 06;81(2):143-51.
147. Gupta M, Dashottar A, Borstad JD. Scapula kinematics differ by body mass index. Journal of applied biomechanics. 2013 Aug;29(4):380-5.
148. Pietilainen KH, Kprio J, Borg P, et al. Physical inactivity and obesity: a vicious circle. *Obesity (Silver Spring)*. 2008;16:409–414.
149. Maffiuletti NA, Jubeau M, Munzinger U, et al. Differences in quadriceps muscle strength and fatigue between lean and obese subjects. Eur J Appl Physiol. 2007;101:51–59.
150. Lockie RG, Murphy AJ, Spinks CD. Effects of resisted sled towing on sprint kinematics in field-sport athletes. The Journal of Strength & Conditioning Research. 2003 Nov 1;17(4):760-7.
151. Kendall FP, McCreary EK, Provance PG, Abeloff D, Andrews PJ, Krausse CC. Muscles, evidence and functions; with Posture and pain. editor Manole; 1995
152. Gross RH. The Pediatric Examination. In: Morrisy RT, Weinstein SL. Pediatric Orthopaedics. Philadelphia: Lippincott-Raven Publishers; 1996:51-89.
153. Tanaka C, Farah EA. Functional anatomy of the muscular chains. Physiotherapy and Research. 1997;4(1):39-40.

Appendix 1 - Body fat percentages and healthy fitness zone

	BOYS							
Age	Aerobic capacity $\dot{V}O_2max$ (ml/kg/min)			Percent body fat				
	PACER, one-mile run, and walk test							
	NI-Health Risk	NI	HFZ	Very Lean	HFZ	NI	NI-Health Risk	
5	Completion of test. Lap count or time standards not recommended.			≤8.8	8.9-18.8	18.9	≥27.0	
6				≤8.4	8.5-18.8	18.9	≥27.0	
7				≤8.2	8.3-18.8	18.9	≥27.0	
8				≤8.3	8.4-18.8	18.9	≥27.0	
9				≤8.6	8.7-20.6	20.7	≥30.1	
10	≤37.3	37.4-40.1	≥40.2	≤8.8	8.9-22.4	22.5	≥33.2	
11	≤37.3	37.4-40.1	≥40.2	≤8.7	8.8-23.6	23.7	≥35.4	
12	≤37.6	37.7-40.2	≥40.3	≤8.3	8.4-23.6	23.7	≥35.9	
13	≤38.6	38.7-41.0	≥41.1	≤7.7	7.8-22.8	22.9	≥35.0	
14	≤39.6	39.7-42.4	≥42.5	≤7.0	7.1-21.3	21.4	≥33.2	
15	≤40.6	40.7-43.5	≥43.6	≤6.5	6.6-20.1	20.2	≥31.5	
16	≤41.0	41.1-44.0	≥44.1	≤6.4	6.5-20.1	20.2	≥31.6	
17	≤41.2	41.3-44.1	≥44.2	≤6.6	6.7-20.9	21.0	≥33.0	
>17	≤41.2	41.3-44.2	≥44.3	≤6.9	7.0-22.2	22.3	≥35.1	

(HFZ = Healthy fitness zone)

Appendix 2: PARTICIPANT DATA COLLECTION SHEET

Participant Number	First Name	Surname	Grade	Age	Weight

Appendix 3: SPEED AND ENDURANCE DATA COLLECTION SHEET

Data Collection Sheet																				
Participant Number																				
Endurance Results																				
Bleep test score																				
Sprint Results Attempt 1																				
10m Sprint (seconds)																				
20m Sprint (seconds)																				
40m Sprint (seconds)																				
Sprint Results Attempt 2																				
10m Sprint (seconds)																				
20m Sprint (seconds)																				
40m Sprint (seconds)																				

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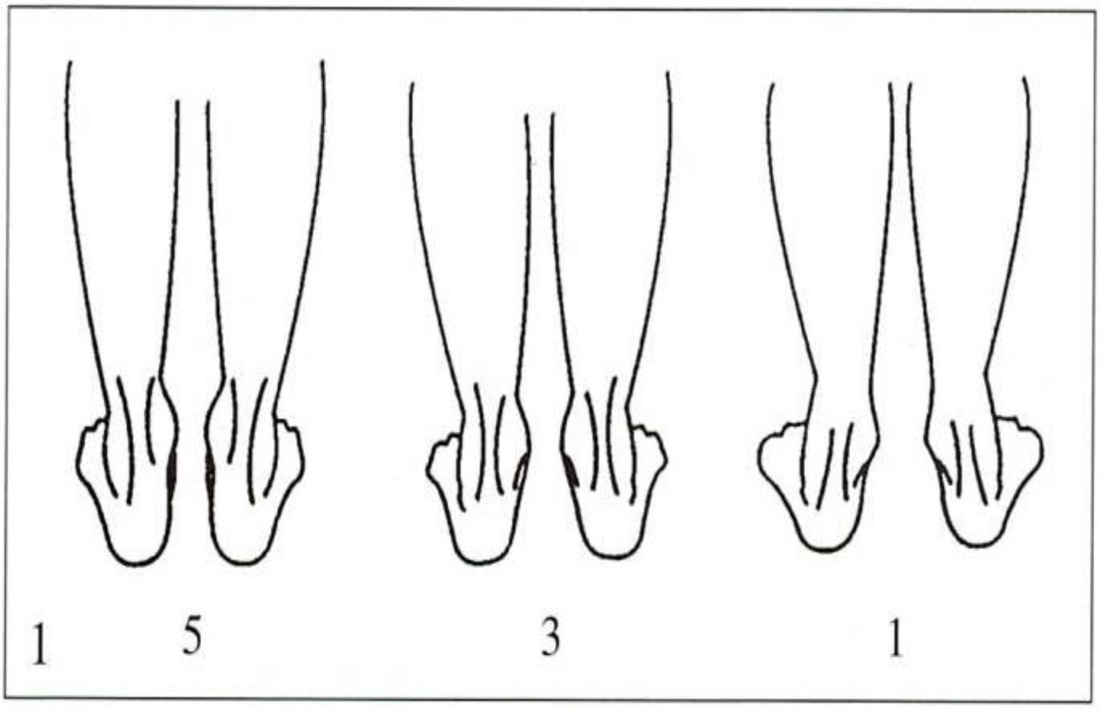
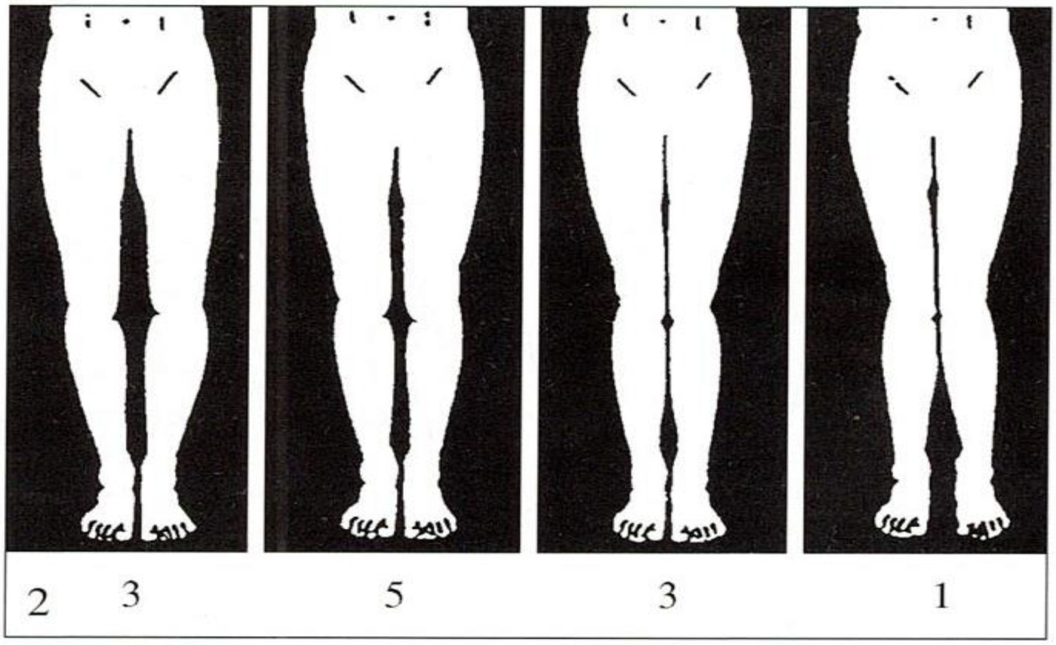
Appendix 4: POSTURE DATA COLLECTION SHEET

Data Collection Sheet																				
Participant Number																				
Postural Scores																				
Knee interspace																				
Shoulder symmetry																				
Knee hyperextension/flexion																				
Lordosis																				
Kyphosis																				
Round shoulders																				
Abducted scapulae																				
Forward head																				
Pelvic Tilt																				
Ankle posture																				
Scoliosis																				
Total Posture																				

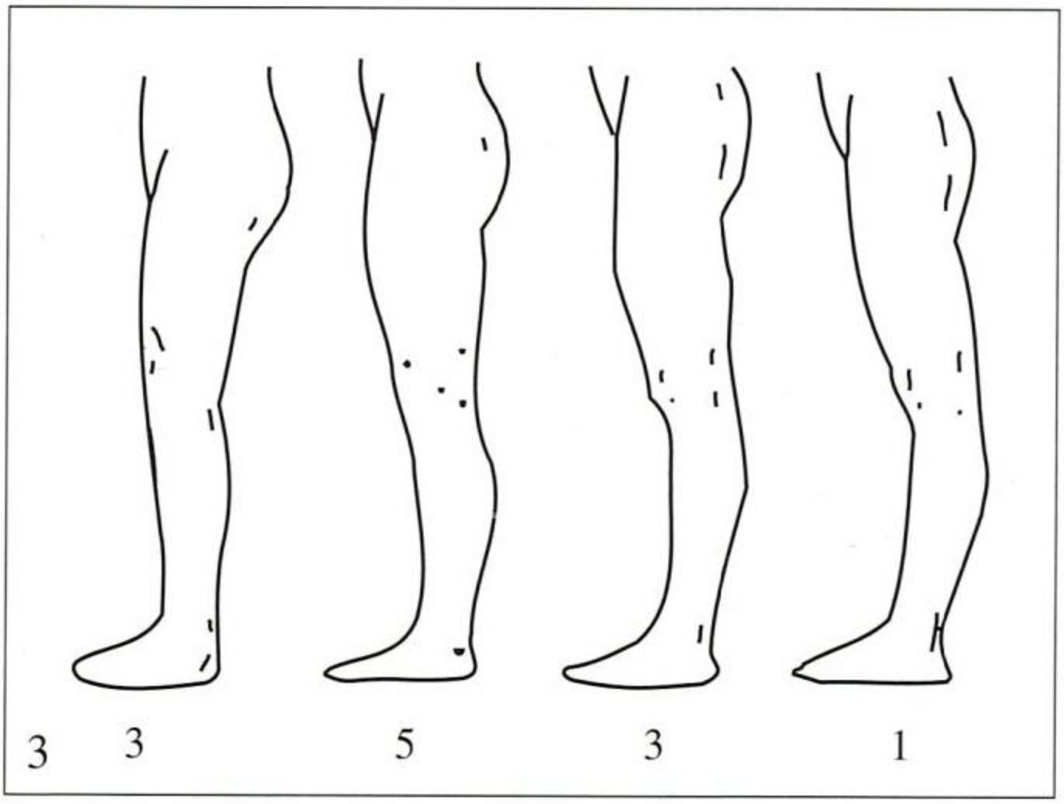
Appendix 5 - Scoring criteria for the assessments of ankle posture. Left indicates good ankle posture. Right indicates marked deviation in ankle posture.



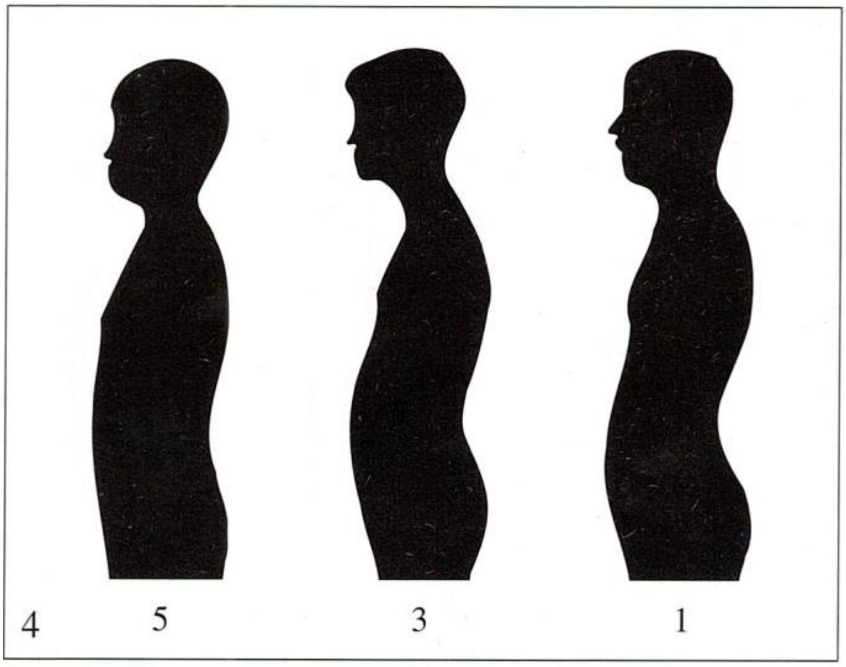
Appendix 6 - Scoring criteria for the assessments of knee interspace. Left indicates knee varus. Right Indicates knee valgus.

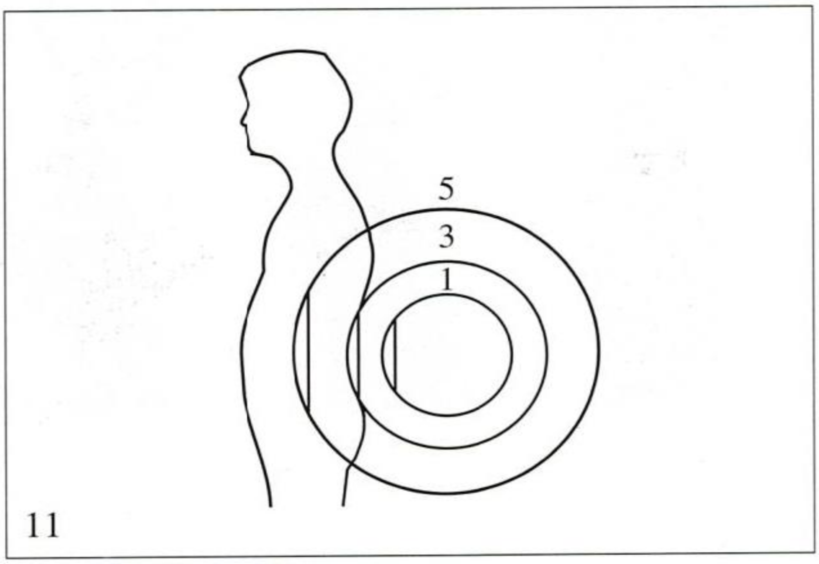


Appendix 7 - Scoring criteria for the assessments of knee hyperextension and flexion. Left indicates knee hyperflexion. Right indicates knee hyperextension.

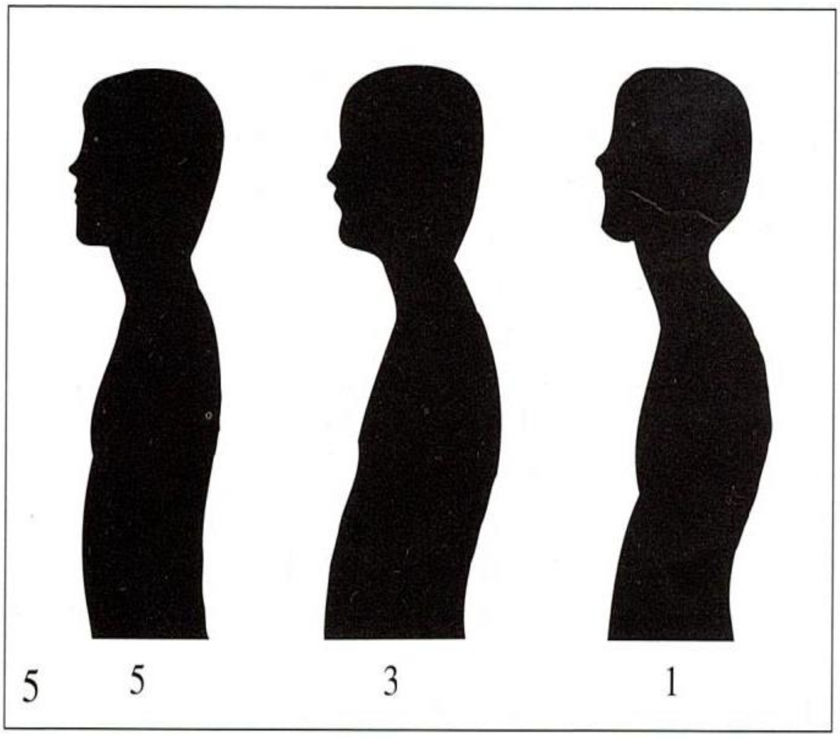


Appendix 8 - Scoring criteria for the assessments of lordosis. Top indicates the scoring criteria of lordosis. Bottom indicates the quantitative procedure to attain the lordosis score.

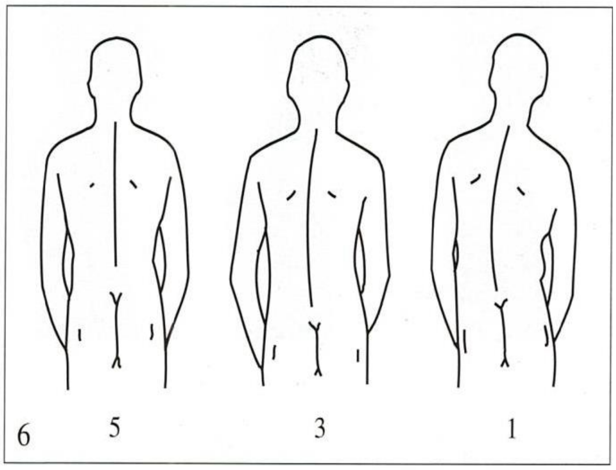


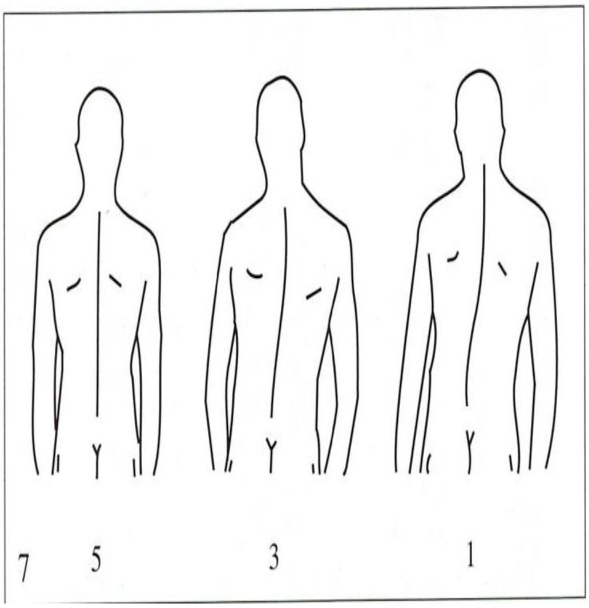


Appendix 9 - Scoring criteria for the assessments of kyphosis. Left indicates good kyphotic posture. Right indicates marked deviation in kyphotic posture.

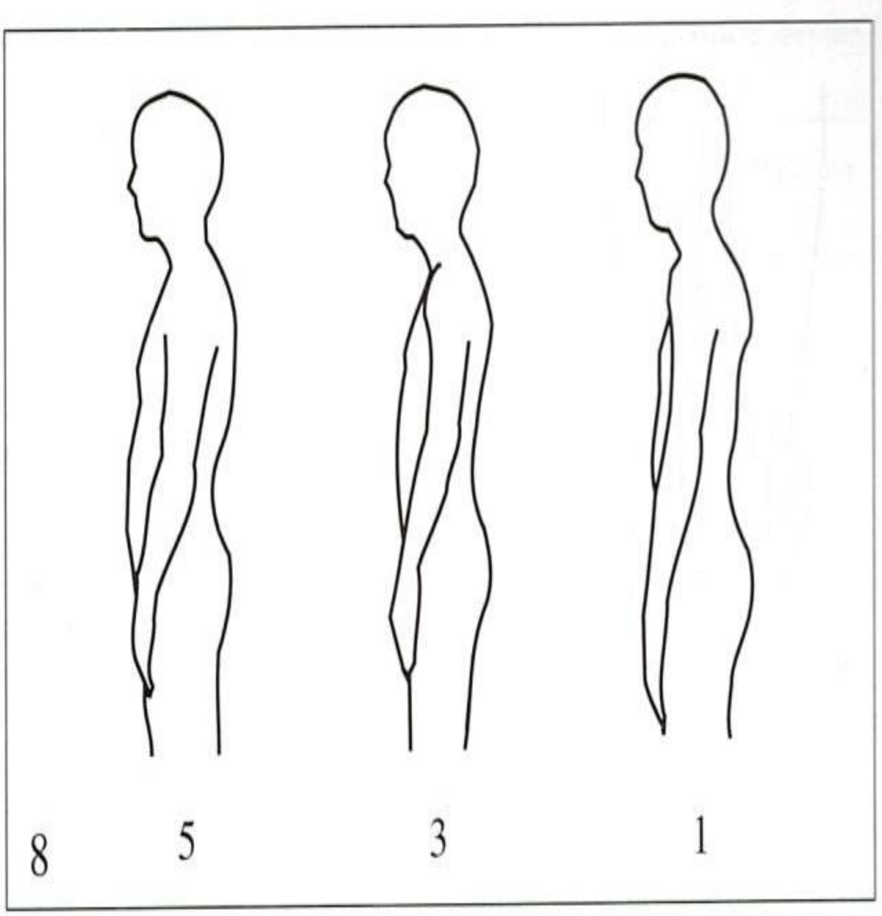


Appendix 10 - Scoring criteria for the assessments of scoliosis. Top indicates the scoring criteria for C-curve scoliosis. Bottom indicates the scoring criteria for S-curve scoliosis.

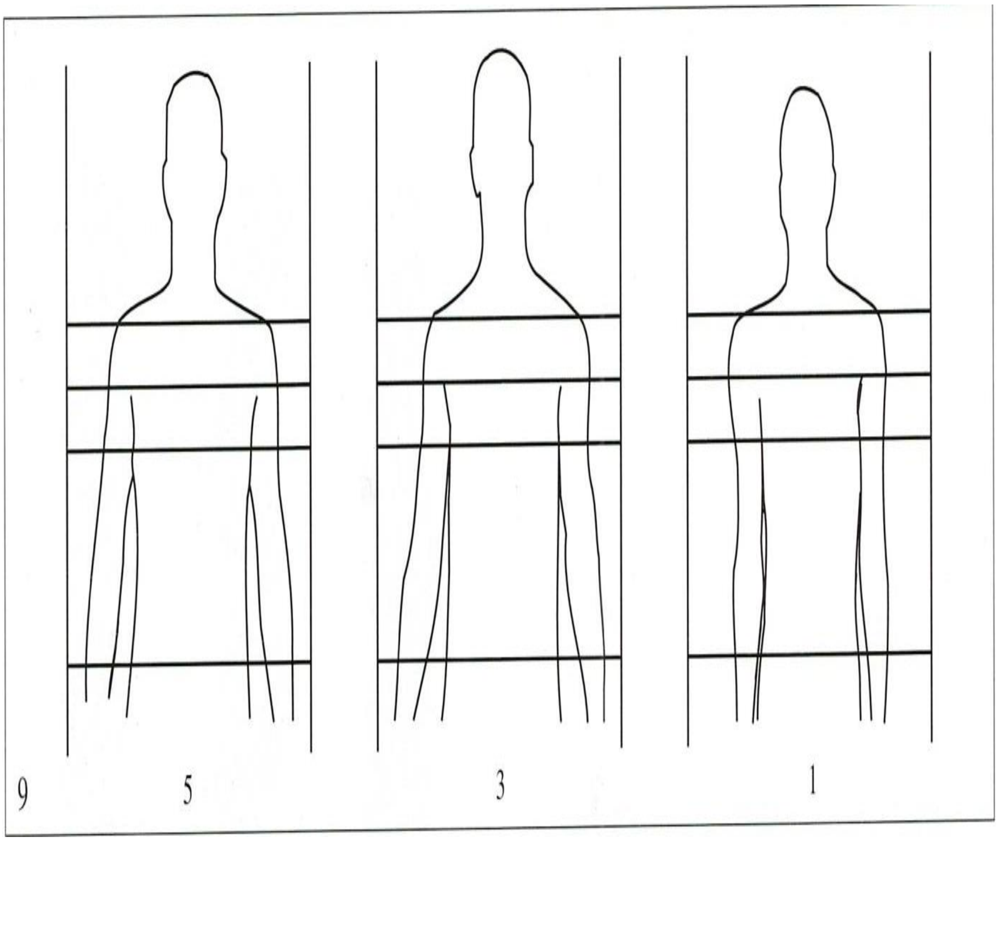




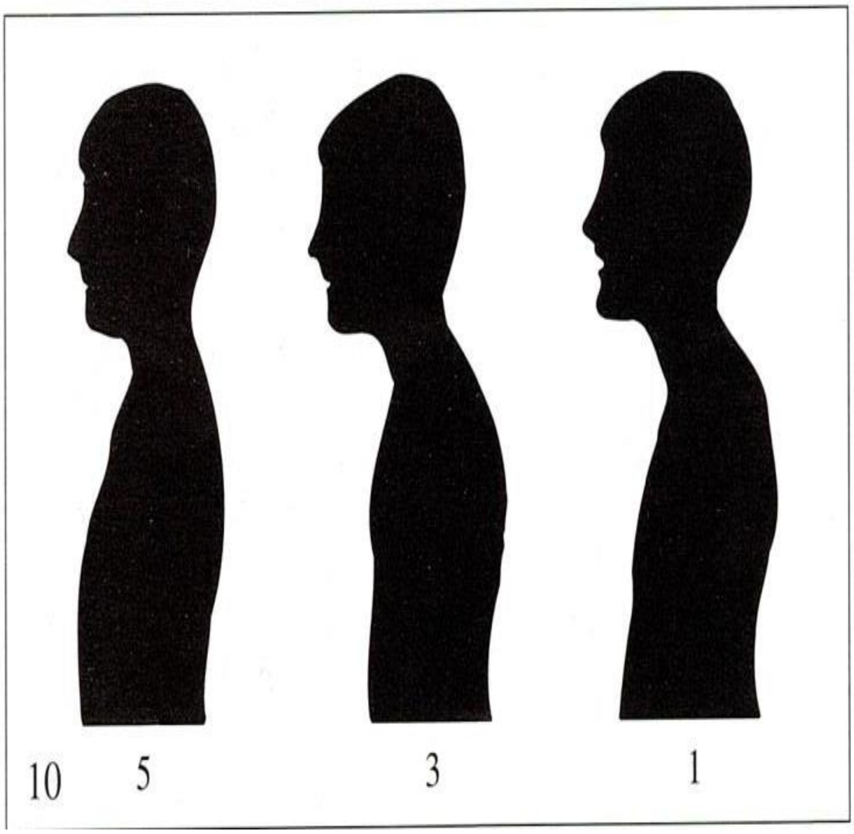
Appendix 11 - Scoring criteria for the assessments of round shoulders and abducted scapulae. Left indicates good shoulder and scapulae posture. Right indicates marked deviations in forward shoulder and abducted scapulae postures.



Appendix 12 - Scoring criteria for the assessment of shoulder symmetry. Left indicates good shoulder symmetry. Right indicates marked deviations in shoulder symmetry.



Appendix 13 - Scoring criteria for the assessment of forward head. Left indicates good head posture. Right indicates marked deviations in head posture.



Appendix 14

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

- FWA 00002567, Approved dd 22 May 2002 and Expires 03/20/2022.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 03/14/2020.

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Faculty of Health Sciences Research Ethics Committee

28/04/2017

Approval Certificate
New Application

Ethics Reference No.: 141/2017

Title: The effect of pre-exercise standing posture on running performance in adolescent males.

Dear Mr Duncan Sutcliffe

The **New Application** as supported by documents specified in your cover letter dated 29/03/2017 for your research received on the 29/03/2017, was approved by the Faculty of Health Sciences Research Ethics Committee on its quorate meeting of 26/04/2017.

Please note the following about your ethics approval:

- Ethics Approval is valid for 3 years
- Please remember to use your protocol number (**141/2017**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:

- The ethics approval is conditional on the receipt of **6 monthly written Progress Reports**, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

*** Kindly collect your original signed approval certificate from our offices, Faculty of Health Sciences, Research Ethics Committee, Tswelopele Building, Room 4.59 / 4.60.*

Dr R Sommers; MBChB; MMed (Int); MPharMed,PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes, Second Edition 2015 (Department of Health).

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Appendix 15

Researcher contact details:

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PARTICIPANT INFORMATION CONSENT DOCUMENT

Dear Participant

You are invited to participate in this research study titled:

"The effect of pre-exercise standing posture on running performance in adolescent males"

This document contains important information pertaining to the study. Please feel free to ask questions if anything is unclear, or if you are uncertain about any aspect of the study.

PURPOSE:

In the study, the researcher will correlate postural assessments to running performances, namely; running speed and running endurance. Relationships obtained through the research process may help identify the link between posture and performance in running. The relationship between pre-exercise standing posture and running performance in adolescents can be used to further increase the pool of knowledge on performance parameters, and thus better the standard of running and reduce the occurrences of running related injuries.

PROCEDURES:

- 10, 20 and 40 metre sprint tests using the HPC photoelectric light system will be conducted to assess the sprint speed abilities of participants (Smart Speed Pro – Fusion Sport).
- A modified postural assessment technique will be used which qualitatively and quantitatively assesses eleven common areas of postural problematic areas.
- The 20-metre shuttle run test using a pre-recorded audio track and a speaker system will be used to assess the aerobic endurance abilities of the participants (Australian Bleep test version).

Three separate days will be used to conduct the full spectrum of testing procedures for each participant. A minimum of 24 hours will be given between each speed and endurance test. Before each speed and endurance testing session, a standardized warm-up of ten minutes will be conducted that will be primarily jogging, running and dynamic stretches. The purpose is to increase muscle/tendon flexibility, minimizing injury, enhance athletic performance, and generally preparing the participants for the workload ahead. For increased reliability, correlations between weight divisions will be used as an alternative to age group divisions to rule out the effects of pubertal influences (ten-kilogram divisions). Body fat percentages will also be to rule out effects of body fat on running performance results. Pre-participation explanations for each testing session will be executed to ensure reliable results and a clear understanding of procedures. It is important to note that the time of test manipulation was not regulated due to the inconsistent participant availability.

5.4.1 Testing day one (Sprint Speed Assessment)

Body fat percentages and body mass will be assessed prior to sprint speed assessments. The use of the HPC photoelectric speed lights will be used at both HPC and a private high school for testing. Sprint speeds of 10m, 20m, and 40m will be assessed. Values will be recorded in (seconds) for completing allocated distances. The better of two attempts per participant will be recorded for data collection. The participant is to give maximal effort in their sprint tests to achieve valid results. The participant will be instructed to wear regular sporting outfits with an emphasis being placed on regular running shoes. Barefoot or running spikes will not be permitted.

5.4.2 Testing day two (Postural Assessment)

Postural assessments will be conducted using both qualitative and quantitative measures. A high-quality HD video camera will be placed perpendicular and centrally 10ft (3,048 metres) from the platform at a height of 120 centimetres. Footage will be in the form of video recorded data instead of photographs for the sole purpose that minor movements may alter postural scores. Dartfish Pro (version 8 and 9) will be used to assessments. When instructed, the participant will rotate and stand 90 degrees clockwise; this will be repeated so that the anterior, lateral and posterior aspect of the participant is recorded. The landmarks will be marked before testing with the use of adhesive dots. This will enable the researcher to more accurately measure and/or calculate certain values for postural scoring. The landmarks are as follows: Patellar notch, greater trochanter, both clavicular heads, both iliac spines, tibial tuberosity, centre of the patellae, C7/T1, T3, T6, T9, T12, L3, L5, most prominent point of the sacrum and the centre of the calcaneus. Participants will be asked to stand completely relaxed, upright, staring ahead with their chin parallel to the ground and fully extend elbows and knees. Fingers and thumbs are to be pointed forward and the participant’s heels should be in contact. Postural rating will be assigned a score of either 5,3 or 1. A score of 5 corresponds to good body mechanics that ranges from no deviation to a level just above that of the previous category. A score of 3 corresponds to a moderate deviation and a score of 1 corresponds to a marked deviation. Overall score of 55 from all 11 postural components corresponds to a perfect posture. Racing tights that are no more than 6mm deep will be worn by all participants.

Postural testing will be compromised of three testing procedures:

- The first procedure involved observing one or two scoring criteria to designate a participant to a qualitative posture category. The 11 separate aspects which will be assessed are as follows: Ankle posture, Knee interspace, Knee hyperextension/flexion, Lordosis, Kyphosis, Scoliosis, Round Shoulders, Abducted Scapulae, Shoulder symmetry and Forward Head. Pelvic Tilt will also be assessed due to its role in running performance.
- The second procedure involved the superimposing of scoring criteria photos onto the videos of participants using Dartfish Pro software (version 8 and 9) to further analyse the postural structures.
- The third procedure was used either to support or reconsider the qualitative judgement and involved the use of quantitative methods of assessment. The analysis of video captured footage in a quantitative method using Dartfish Pro software (version 8 and 9). This allows for pinpoint analysis of postural deviances and thus furthers the validity of results. The third procedure will be the deciding deduction if first and second procedures are conflicting.

Testing Day 3 (Aerobic Endurance Assessment)

The 20m shuttle run test (Bleep Test) will be conducted. Scores obtained will be in the form of running stage number, which will then be converted to distance covered meters. The participant is to give maximal effort in their bleep test to achieve valid results. The participant will be instructed to wear regular sporting outfits with an emphasis being placed on regular running shoes. Barefoot or running spikes will not be permitted.

RISKS AND DISCOMFORTS:

Risks associated with the study include, but are not limited to, muscle pain, muscle stiffness, fatigue, and in rare instances dizziness. In the case of an acute adverse event the patient will be referred or treated by medical personnel at the University of Pretoria. The risks associated with the study are based primarily on the sprint and endurance tests which require maximal efforts, and thus increased susceptibility of injuries. Participation in the study remains voluntarily; this will be made clear in the explanation and consent/assent forms. The participants are allowed to stop the tests at any time if necessary. Risks will be reduced by implementing an in-depth explanation of all testing procedures. Furthermore, the risk of sustaining an injury will be reduced by conducting and foreseeing an effective warm up for each physical test.

EXCLUSION CRITERIA:

- Individuals with any present injuries or illnesses that may prevent maximal effort in performance testing will be excluded from the study.
- Female individuals may not participate in the study.
- Individuals with body fat percentages greater than the prescribed health fitness zone may not participate in the study.
- Individuals who have muscle soreness or stiffness from various other sporting activities, that may prevent maximal effort in performance testing will be excluded from the study.

BENEFITS:

Positive benefits to the participants would include general postural analysis, as well as running performance assessments. Any postural imbalances identified may have detrimental effects on performances in an array of sporting codes, as well as their general health. Interventions can be implemented at every educational level to identify, correct and maintain postural imbalances which may prevent long term effects on the individual. Specialised postural improvement programs may benefit all individuals regardless of postural statuses

CONFIDENTIALITY:

Participation in the study remains voluntarily; this will be made clear in the explanation and consent/assent forms. The participants can stop the tests at any time if necessary. The raw data obtained from the players will be kept up to 15 years. Anonymity will be maintained throughout the full testing procedure by use of a numbering system. The names of all participants involved will not be published or presented.

Take note that your participation is voluntary and that you are not being forced to take part in this study. Although you agree to participation, you retain the right to withdraw from participation in the study at any time, without negative consequences.

I, ____ (full name of participant), have read the above information and have been informed of the procedures, requirements, benefits and risks of participating in this research project.

I hereby also grant permission to participate in this research study and that I will not withhold any information that may be of importance to the researcher. I hereby also grant the researcher permission to use my data of my participation in this study and that my results may be used for publication and/or presentation purposes, with anonymity ensured.

___________________________ ___________________________

Full names or participant Signature of participant

____

Signature of witness

___________________________ ___________________________

Signature of researcher Date

UNIVERSITEIT VAN PRETORIA
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YUNIBESITHI YA PRETORIA

FACULTY OF HEALTH SCIENCES

Http://www.up.ac.za

Appendix 16

PARTICIPANT INFORMATION ASSENT DOCUMENT

Dear Participant

You are invited to participate in this research study titled:

"The effect of pre-exercise standing posture on running performance in adolescent males"

You will form part of the research study where your body posture, running speed, and running fitness levels will be tested. Body posture is a major aspect of general health, as well as sporting performances. The aim of the research being conducted is to identify whether your posture may affect your running abilities.

About 60 students from a private high school and 30 athletes for the HPC High School are going to take part in this study. Testing will take place from June 2017 – March 2018. The running tests must be completed as best you can. The posture tests are pain free and very quick. Testing will occur over three separate days.

- Day 1 is the Running Speed Tests
- Day 2 is the Running Fitness Tests
- Day 3 is the Posture Tests

Any postural problems that you may have, may reduce your sporting performances and reduce the general health.

If you do not want to take part or you may decide not to carry on. No-one will force you to carry on. Speak to your parents and/or guardians when deciding whether to take part.

If you sign at the bottom it will mean that you have read this paper, and that you would like to be in this study

____________________________ Full names or participant

____________________________ Signature of participant/guardian

____________________________ Signature of witness

____________________________ Signature of researcher

____________________________ Date

Appendix 17

FACULTY OF HEALTH SCIENCES

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UNIVERSITEIT VAN PRETORIA
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YUNIBESITHI YA PRETORIA

Protocol No. ____________________

Principal Investigator(s) Declaration for the storage of research data and/or documents

I, the Principal Investigator(s) Duncan Peter Sutcliffe of the following trial/study titled: ***The effect of pre-exercise standing posture on running performance in adolescent males,*** will be storing all the research data and/or documents referring to the above mentioned trial/study at the following address: Department of Physiology, Division (Biokinetics and Sports Science), LC de Villiers Sports Ground.

I understand that the storage for the abovementioned data and/or documents must be maintained for a minimum of 15 years from the commencement of this trial/study.

START DATE OF TRIAL/STUDY: August 2016

END DATE OF TRIAL/STUDY: August 2018

UNTIL WHICH YEAR WILL DATA WILL BE STORED: August 2033

Name: **Duncan Peter Sutcliffe**

Signature:

Date: **2017-02-01**

Appendix 18

FACULTY OF HEALTH SCIENCES

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Http://www.up.ac.za

Subject: Permission letter to use HPC facilities for research testing.

TO WHOM IT MAY CONCERN

I am hereby asking permission to use the nearest field to the HPC building, as well as the biomechanics screening room for data collection. The purpose is to collect data on adolescent males in the HPC School (Athletics Division). The data includes: Postural, speed and endurance assessments.

Permission from the coaches will also be attained.

We will need access to the facilities in 2017 (April - June) if possible.

Thank you for your consideration.

Duncan Sutcliffe
0822263506
sutters9393@gmail.com

Date

2017-02-07

Signature of HPC Manager

Appendix 19

FACULTY OF HEALTH SCIENCES

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Http://www.up.ac.za

Subject: Permission letter to use St Albans College facilities for research testing.

TO WHOM IT MAY CONCERN

I am hereby asking permission to please use the biomechanics screening room as well as the nearest field for data collection. The purpose is to collect data on adolescent males in the St Albans College School. The data includes: Postural, speed and endurance assessments.

We will need access to the facilities 2017 (April – December) during school PHYSED classes if possible.

Thank you for your consideration.

Duncan Sutcliffe
0822263506
sutters9393@gmail.com

Date

08 February 2017

Signature of Head of Sport

Appendix 20

FACULTY OF HEALTH SCIENCES

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Http://www.up.ac.za

SUBJECT: PERMISSION LETTER TO HPC FOR THE USE OF EQUIPMENT FOT TESTING

TO WHOM IT MAY CONCERN.

We are hereby asking permission to use the speaker system, bleep test flash disk, extension cable, stadiometer, tape measure, tanita scale and the photoelectric speed lights for the HPC testing.

We are also asking for permission to use the tape measure, bleep test flash disk, stadiometer, tanita scale and photoelectric speed lights units for the testing at St Albans College.

The purpose is to collect data in 2017 (April – June)

We will need access to the equipment for 1 day each session if possible.

Duncan Sutcliffe
0822263506
sutters9393@gmail.com

Date

2017.02.07

Signature of Sport Science HPC

Appendix 21

FACULTY OF HEALTH SCIENCES

Http://www.up.ac.za

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

SUBJECT: PERMISSION LETTER TO ST ALBANS COLLEGE FOR THE USE OF EQUIPMENT FOR TESTING

TO WHOM IT MAY CONCERN.

We are hereby asking permission to use the speaker system and extension cable for the testing which will be conducted at St Albans College

The purpose is to collect data in 2017 (April – December)

We will need access to the equipment for 1 day each session if possible.

Duncan Sutcliffe
0822263506
sutters9393@gmail.com

Date

08 February 2017

Signature of St Albans College Sports Office

Appendix 22

RESEARCH PROPOSAL AND ETHICS COMMITTEE
(RESPEthics)

FACULTY OF HEALTH SCIENCES

UNIVERSITY OF PRETORIA

DECLARATION OF ETHICAL INTENT

I declare that I am fully aware of the stance taken by the RESPEthics Committee, Faculty of Health Sciences, regarding the importance of obtaining informed consent from research participants.

I acknowledge their concerns and reservations regarding the lack of written informed consent documents due to the fact that we deem it impossible to obtain such in the current research project.

I declare that, in the course of the research, I will take due care to protect and safeguard the rights and autonomy of all parties, which includes the participants, the University of Pretoria, RESPEthics, our Department and all outside parties with whom we make contact either physically, verbally or through documents and documentation.

I undertake to be ethical in all our dealings and at all times during the research endeavour.

STUDENT:	Mr Duncan Peter Sutcliffe
SUPERVISOR:	Dr Kim Nolte
HEAD OF DEPARTMENT:	Professor Annie Joubert
PROJECT TITLE:	**The effect of pre-exercise standing posture on running performance in adolescent males**