COURSE GUIDE

KHE 335
MOTOR LEARNING AND HUMAN PERFORMANCE

Course Team

Dr. S. M. Bichi (Course Writer) – ABU Zaria
Professor S. S. Hamafyelto (Course Editor) – University of Maiduguri

NATIONAL OPEN UNIVERSITY OF NIGERIA

National Open University of Nigeria
Headquarters
University Village
Plot 91, Cadastral Zone
Nnamdi Azikiwe Expressway
Jabi, Abuja

Lagos Office
14/16 Ahmadu Bello Way
Victoria Island, Lagos

e-mail: centralinfo@nou.edu.ng
URL: www.nou.edu.ng

Printed 2021

ISBN: 978-978-058-300-2

CONTENTS **PAGE**

INTRODUCTION

Motor Learning and human performance involves organisation of experience and analysis of theoretical structure of man's movement pattern with emphasis on psychological correlates of such education. Other aspects of the course include factors relating to the acquisition and performance of motor skills etc. should be discussed.

COURSE COMPETENCIES

This course aims at providing you with relevant information on motor learning and human performance.

COURSE OBJECTIVES

By the end of this course, you will be able to:

- discuss the meaning of learning theories
- state the muscular system of human body
- mention the major application of motor learning and human performance
- describe the measures of mortality statistics

(i) The concepts of Motor Skill
(ii) Groups of Motor Skills
(iii) Factors that Influence Motor Skill Learning.

WORKING THROUGH THIS COURSE

You need to read this course materials, each unit with good understanding you should be able to execute the self-assessment exercises in each of the units very correctly.

STUDY UNITS

There are 9 study units in this course divided into 4 modules. The modules and units are presented as follows:

Module 1

Unit 1 Motor Skill
Unit 2 Group Motor Skills

Module 2

Unit 1 Motor Development
Unit 2 Psychological Factors

Module 3

Unit 1 Motor Control
Unit 2 Theories of Motor Control
Unit 3 Motor Programs and Central Pattern Generators

Module 4

Unit 1 Kinaesthesia
Unit 2 Skin and Sensory Function

REFERENCES AND FURTHER READING

Adams J. A. (1971). A Closed-Loop Theory of Motor Learning. J Mot Behavior.

Breedlove S. M, et al. (2010). Biological Psychology: An Introduction to Behavioral, Cognitive, and Clinical Neuroscience. Sinauer Associates Inc., Sunderland, MA, USA.

Hallgató E, et al. (2012). The Differential Consolidation of Perceptual and Motor Learning in Skill Acquisition. Cortex. In Press.

Kantak S. S, &Winstein C. J. (2012). Learning-Performance Distinction and Memory Processes for Motor Skills: A Focused Review and Perspective. Behave Brain Res 228: 219-231.

Keele S. W. (1968). Movement Control in Skilled Motor Performance. Psychol Bull 70: 387-403.

Kimble G. A. (1961). Hilgard and Marquis Conditioning and Learning. Appleton-Century- Crofts, Inc, New York.

Schmidt R. A. (1975). A Schema Theory of Discrete Motor Skill Learning. Psychol Rev.

Squire L. R. (1987). Memory and Brain. New York: Oxford University Press.

Squire L. R. & Wixted J. T. (2011). The Cognitive Neuroscience of

Human Memory since H.M. Annu Rev Neurosci.

Whiting H. A. (1975). Concepts in Skill Learning. Lepus Book, London.

PRESENTATION SCHEDULE

The presentation schedule gives you the important dates for completion of your computer-based tests, participation in forum discussions and participation at facilitation. Remember, you are to submit all your assignments at the appropriate time. You should guide against delays in submitting your computer-based tests.

ASSESSMENT

There are two main forms of assessments in this course that will be scored: The Continuous Assessment and the Final Examination. The continuous assessment shall be in three fold. **There will be three Computer Based Assessments. The computer-based assessments will be given in accordance to university academic calendar. The timing must be strictly adhered to**. The Computer Based Assessments shall be scored a maximum of 10% each. Therefore, the maximum score for continuous assessment shall be 30% which shall form part of the final grade.

The final examination for KHE335 will be maximum of two hours and it takes 70 per cent of the total course grade. The examination will consist of 70 multiple choice questions that reflect cognitive reasoning.

FINAL EXAMINATION AND GRADING

The final examination in this course carries 70%. You are expected to sit for this final examination in your various Study Centres.

HOW TO GET THE MOST FROM THE COURSE

To get the most in this course, you need to have a personal laptop and internet facility. This will give you adequate opportunity to learn anywhere you are in the world. Use the Ojectives to guide your self-study in the course. At the end of every unit, examine yourself with the objectives and see if you have achieved what you need to achieve.

Carefully work through each unit and make your notes. Join the online real time facilitation as scheduled. Where you missed the scheduled online real time facilitation, go through the recorded facilitation session at your on free time. Each real time facilitation session will be video recorded and posted on the platform.

In addition to the real time facilitation, watch the video and audio recorded summary in each unit. The video/audio summaries are directed to salient part in each unit. You can access the audio and videos by clicking on the links in the text or through the course page.

FACILITATION

You will receive online facilitation. The facilitation is learner centered. The mode of facilitation shall be asynchronous and synchronous. For the asynchronous facilitation, your facilitator will:

- Present the theme for the week;
- Direct and summarise forum discussions;
- Coordinate activities in the platform;
- Score and grade activities when need be;
- Upload scores into the university recommended platform;
- Support you to learn. In this regard personal mails may be sent;
- Send you videos and audio lectures; and podcast.
- For the synchronous:
- There will be eight hours of online real time contact in the course. This will be through video conferencing in the learning management system. The eight hours shall be of one-hour contact for eight times.
- At the end of each one-hour video conferencing, the video will be uploaded for view at your pace.
- The facilitator will concentrate on main themes that students must-learn in the course.
- The facilitator is to present the online real time video facilitation time table at the beginning of the course.
- The facilitator will take you through the course guide in the first lecture at the start date of facilitation.

Do not hesitate to contact your facilitator. Contact your facilitator if you:

- Do not understand any part of the study units or the assignment.
- Have difficulty with the self-assessment exercises
- Have a question or problem with an assignment or with your tutor's comments on an assignment.
- Also, use the contact provided for technical support.
- Read all the comments and notes of your facilitator especially on your assignments: participate in the forums and discussions. This gives you opportunity to socialize with others in the programme. You can raise any problem encountered during your study. To gain the maximum benefit from course facilitation, prepare a list of

questions before the discussion session. You will learn a lot from participating actively in the discussions.

- Finally, respond to the questionnaire. This will help the university to know your areas of challenges and how to improve on them for the review of the course materials and lectures.

MAIN COURSE

CONTENTS **PAGE**

MODULE 1

Unit 1 Motor Skill
Unit 2 Group Motor Skills

UNIT 1 MOTOR SKILL

CONTENTS

1.0 INTRODUCTION

A motor skill is learned ability to cause a predetermined movement outcome with maximum certainty. Motor learning is a relating*(timel*y) permanent change in the ability to perform a skill as a result of practice or experience. (source). Performance is an act of executing a motor skill. The goal of motor skill is to optimize the ability to perform the skills at the rate of success, precession and to reduce the energy consumption required for performance. Continuous practice of a specific motor skill will result in a greatly improved performance, but not all movement are motor skill (Wikipedia. Com 2019).

2.0 OBJECTIVES

At the end of the lesson the students will be able to learned the following:

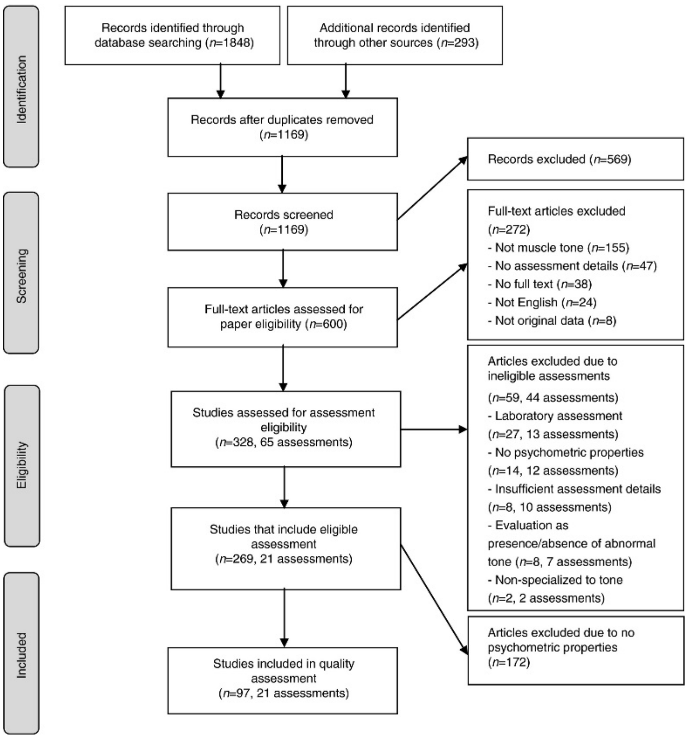
- The concepts of Motor Skill.
- Factors that influence motor skill

3.0 MAIN CONTENT

3.1 Definition of Motor Skill

A motor skill is learned ability to cause a predetermined movement outcome with maximum certainty. Motor learning is a relating permanent change in the ability to perform a skill as a result of practice or experience. Motor skill learning has been defined as a set of internal processes associated with practice or experience leading to relatively permanent changes in the ability for skilled behavior. in other words, motor skill learning is when complex processes in the brain occur in response to practice or experience of a certain skill resulting in change in the central nervous system that allow for production of new motor skill. Wikipedia. Com (2019) define motor skill learning as a learned ability to cause a predetermined movement outcome with maximum certainty. Motor skill learning is the relatively permanent change in the ability to perform a skill as a result of practice or experience performance as an act of executing motor skill.

According to James C. Houck (2018) motor skill learning is a variety of motor skill occur in various forms of movement: work, play, sport, communication, dance and so on. The theoretical and operational emphasis of this field parallel to those in sub domain of learning, and cognitive skill not mutually exclusive and in part because of anatomical advances that show the underlying modular architecture of the brain.



www. Musclestone. Hty. Gh. 2021.

- **Gender:** By gender we mean sex both boys and girls, gender play important role in developing motor skill. Boys have more advance motor skill than girls because there are typically strong and more aggressive while girls have advance eye and hand to coordination's, they have low central of gravity which make them in both fine gross motor skills.

3.2 Factors that influence Motor Skill

Sharon Boiling (2017) states that, many factors impacts the rate at which children develop motor skills: Environmental, cultural and social factors all play a role, while there are genetic aspects to consider when evaluating gross and fine motor skills, most researchers agree that non genetic factors have an equal effect.

3.2.1 Environmental Factors

A child's living conditions, level of parental involvement and educational experiences all affect motor skill development, According to a 2009 article for the "early children education journal. "titled "environmental factors affecting pre-schoolers motor development" parent and caregivers influence the level at which a child develop motor skills. The articles explain that higher socioeconomic status and intellect positively correlate with more advance motor development *source*. Parent and caregivers who provide consistent opportunities for active play encourages the growth of motor skill in a child's environments at home and at schools.

3.2.2 Cultural Factors

A child's culture directly influences the rate and level of motor skills development. Typically, American child roll (s) over at the rate of 3 months, sit (s) at 6 months, and walk (s) at 12 months, however, in other cultures around the world, the time frame for development can differ. Natural observation of the world's cultures shows that climate, housing, and culturally based child-rearing practice (s) strongly impact the development of motor skills.

3.2.3 Social Factors

Self-perception and self-motivation are example of social indicators that impact motor skill development. Albert bandura whose social Learning theory focusses on how child learn in all areas of development suggest that children who believe they can acquire new skill are more likely to try harder when challenged, less likely to become discourage and more likely to positively reacts to learning experiences, however, children who view their aptitude tend to have a negative reaction when they have trouble mastering a skill.

Robert S. (2018) stated that, there are several different factors that affect motor development, which include growth, environment, genetics, muscles tone and gender. We will explore each of these factors individually.

SELF – ASSESSMENT EXERCISE

i. Define Motor Skill?
ii. Factors that influence motor skill

4.0 CONCLUSION

Motor competence reflects the degree of proficient performance in various motor skills and is essential for developing an active and healthy lifestyle. If a child has motor problems and is left untreated, he is likely to transfer them into adulthood. Moreover, low motor competence can lead to risks for a mixture of behavioral, emotional, and social difficulties. Additionally, it also significantly impacts the willingness of participation in physical activity and overall performance in different sports.

5.0 SUMMARY

Here we need to acknowledge the role of the Central Nervous System (CNS), which integrates the whole process in order to function with appropriate movement behaviors in a changing environment. The CNS gets activated to identify and perceive sensory inputs, and thereafter to determine useful actions, and then to execute those actions with correct movement sequencing, timing, and coordination. All of these brain activities are referred to as information processing system. Information processing as a system could be conceived as the way of explaining how human beings think and perform deliberate and conscious actions. In motor learning context, it explains how athletes consciously interpret, understand and control their movements. Now the question pertains as to how much it is crucial to for the coaches or trainers to follow this model of information.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the term Motor Skill.
2. Factors that influence motor skill

7.0 REFERENCES/FURTHER READING

Robert S. (2018), Factors influencing motor development: chapter 10/lesson 9. study.Com.

James C. Houck (2018). Detonation of motor skill learning. Wikipedia. Com.

Sharon H. Boiling (2017). Environmental, cultural and social factors that influence motor skill development in children.

Schmidt R.A. (1975). A schema theory of discrete motor skill learning. Psychol Rev.

Whiting H.A. (1975). Concepts in Skill Learning. Lepus Book, London.

Kantak S.S, Winstein C.J. (2012). Learning-performance distinction and memory processes for motor skills: a focused review and perspective. Behave Brain Res 228: 219-231.

Hallgató E, Győri-Dani D, Pekár J, Janacsek K, Nemeth D. (2012). The differential consolidation of perceptual and motor learning in skill acquisition. Cortex. In press.

UNIT 2 GROUP MOTOR SKILLS

CONTENTS

1.0 INTRODUCTION

A motor skill is learned ability to cause a predetermined movement outcome with maximum certainty. Motor learning is a relating*(timel*y) permanent change in the ability to perform a skill as a result of practice or experience. (source). Performance is an act of executing a motor skill. The goal of motor skill is to optimize the ability to perform the skills at the rate of success, precession and to reduce the energy consumption required for performance. Continuous practice of a specific motor skill will result in a greatly improved performance, but not all movement are motor skill (Wikipedia. Com 2019).

2.0 OBJECTIVES

At the end of the lesson the students will be able to learned the following:

- Groups of Motor Skills.
- Muscles Tones
- Growth of the child

3.0 MAIN CONTENT

3.1 Definition of Groups of Motor Skill

Stallings, Loretta. (2015) motor skill are movements and actions of the muscles. typically, they are categorized into two groups: *why not new* APA *style* of *citations and referencing*

- **Gross motor skill**

This requires the use of large muscles groups to form a task like walking, balancing and crawling. The skill required is not extensive and therefore are usually associated with continuous task, much of the development of those skill occur during early childhood. The performance level of gross motor skill remains unchanged after periods of non-use.

- **Fine motor skill**

This required the use of smaller muscle group to perform smaller movement with the wrists, hands, finger and the feet and toes. These task that are precise in nature, like playing the piano, writing carefully and blinking generally. There is retention loss of fine motor skill over a period of non-use.

In children, a critical period for the acquisition of motor skill is preschool year (age 3-5) as fundamental neuroanatomic structure shows significant development, elaboration and myelination over the course of this period. Many factors contribute to the rate that children develop their motor skill, unless afflicted with a sever disability, children are expected to develop a wide range of basic movement abilities and motor skill. Motor development progresses in seven stage throughout an individual's life: reflective, rudimentary, fundamental, sports skill, growth and refinement, peak performance and regression. A motor skill is learned ability to cause a predetermined movement outcome with maximum certainty. Motor learning is a relating permanent change in the ability to perform a skill as a result of practice or experience.

Motor skill learning has been defined as a set of internal processes associated with practice or experience leading to relatively permanent changes in the ability for skilled behavior. in other words, motor skill learning is when complex processes in the brain occur in response to practice or experience of a certain skill resulting in change in the central nervous system that allow for production of new motor skill. Wikipedia. Com (2019) define motor skill learning as a learned ability to cause a predetermined movement outcome with maximum certainty. Motor skill learning is the relatively permanent change in the ability to perform a skill as a result of practice or experience performance as an act of executing motor skill.

According to James C. Houck (2018) motor skill learning is a variety of motor skill occur in various forms of movement: work, play, sport, communication, dance and so on. The theoretical and operational emphasis of this field parallel to those in sub domain of learning, and cognitive skill not mutually exclusive and in part because of anatomical advances that show the underlying modular architecture of the brain.

3.2 Growth of the child

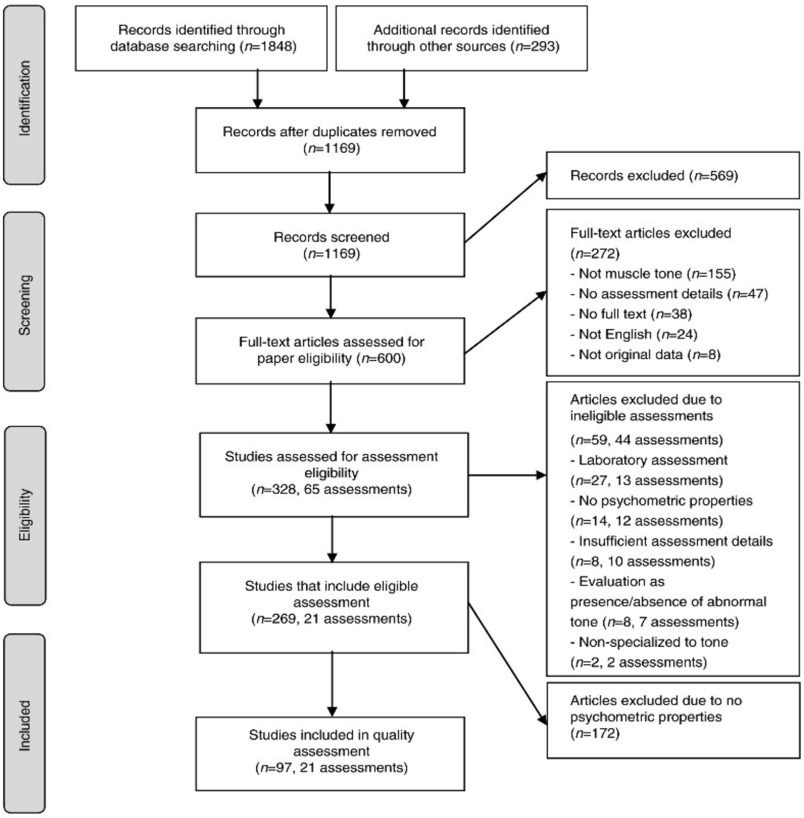
Most motor development skill has age specific target ranges, the skills are also influence by children being smaller or tall for their age, their weight and their mental development.

- **Environment**: Gross and fine motor skill increase when children are encouraged to play with their hands, hold and touch smaller items, feed themselves and draw or colors.
- **Genetic**: Children are affected both by the genetic of their parents and their own genetic. If there are genetic weakness, they may have slower motor skill development than general guidelines suggest for their age range.

3.3 Muscles tone

As mentioned earlier, muscles tone can affect motor skills. The stronger a child is, the more ability the may have to move and control their body. Muscle are a fundamental factor in a child having the strength to move their body and control their action e.g.

www. Musclestone. Hty. Gh. 2021.



www. Musclestone. Hty. Gh. 2021.

- **Gender:** By gender we mean sex both boys and girls, gender play important role in developing motor skill. Boys have more advance motor skill than girls because there are typically strong and more aggressive while girls have advance eye and hand to coordination's, they have low central of gravity which make them in both fine gross motor skills.

SELF – ASSESSMENT EXERCISE

i. Define Motor Skill?
ii. Explain Muscles Tones
iii. What is Growth of the child

4.0 CONCLUSION

Motor competence reflects the degree of proficient performance in various motor skills and is essential for developing an active and healthy lifestyle. If a child has motor problems and is left untreated, he is likely to transfer them into adulthood. Moreover, low motor competence can lead to risks for a mixture of behavioral, emotional, and social difficulties. Additionally, it also significantly impacts the willingness of participation in physical activity and overall performance in different sports.

5.0 SUMMARY

Here we need to acknowledge the role of the Central Nervous System (CNS), which integrates the whole process in order to function with appropriate movement behaviors in a changing environment. The CNS gets activated to identify and perceive sensory inputs, and thereafter to determine useful actions, and then to execute those actions with correct movement sequencing, timing, and coordination. All of these brain activities are referred to as information processing system. Information processing as a system could be conceived as the way of explaining how human beings think and perform deliberate and conscious actions. In motor learning context, it explains how athletes consciously interpret, understand and control their movements. Now the question pertains as to how much it is crucial to for the coaches or trainers to follow this model of information.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term Motor Skill
2. Draw a human Muscles Tones
3. Illustrate the Growth of the child

7.0 REFERENCES/FURTHER READING

Robert S. (2018), Factors influencing motor development: chapter 10/lesson 9. study.Com.

James C. Houck (2018). Detonation of motor skill learning. Wikipedia. Com.

Sharon H. Boiling (2017). Environmental, cultural and social factors that influence motor skill development in children.

Schmidt R.A. (1975). A schema theory of discrete motor skill learning. Psychol Rev.

Whiting H.A. (1975). Concepts in Skill Learning. Lepus Book, London.

Kantak S.S, Winstein C.J. (2012). Learning-performance distinction and memory processes for motor skills: a focused review and perspective. Behave Brain Res 228: 219-231.

Hallgató E, Győri-Dani D, Pekár J, Janacsek K, Nemeth D. (2012). The differential consolidation of perceptual and motor learning in skill acquisition. Cortex. In press.

MODULE 2

UNIT 1 MOTOR DEVELOPMENT

CONTENTS

1.0 INTRODUCTION

Development results from the interrelated processes of maturation, physical growth, and learning and may be observed in genetic and environmental adaptation. Maturation guides development genetically in the physical changes that occur during organ differentiation in the embryo, myelination of nerve fibers, and the appearance of primary and secondary ossification centers. Growth is the process whereby changes in physical size and shape take place, as witnessed during adolescence when dramatic changes in facial and body growth occur. Adaptation, on the other hand, is the body's response to environmental stimuli. A muscle increases bulk with strength training, the immune system produces antibodies when exposed to a pathogen, bones heal after a fracture. All of these processes illustrate adaptation. Researchgate.net

2.0 OBJECTIVES

After studying this chapter, the reader will be able to:

- Define motor development.
- Understand the relationship between motor development and dynamic systems theory.

3.0 MAIN CONTENT

3.1 Meaning of Motor Development

Motor development is the change in motor behavior experienced over the life span. The process and the product of motor development are related to age, and motor development's study has roots in biology and psychology. Typically, researchers in motor development study individuals of different ages performing the same task, describe age differences in terms of performance, and suggest age-appropriate standards for judging the motor performance of infants, children, teenagers, adults, and older adults. Motor development studies are less likely to be concerned with changing one's performance than with documenting naturally occurring age-related change. Motor behavior changes occur to meet our needs across the life span. Observable changes are the result of the interaction between biological and environmental factors. Biological factors are not stable over time and are evidenced by differences in rate of growth, magnitude of growth, sensory processing, flexibility, strength, and speed of response. Maturation and learning depend on each other because learning does not occur unless the system is ready to learn.

The rate of maturation is affected by the amount and type of learning experiences, and the type of learning experiences is affected by the sociocultural environment. Environmentally, the variables are infinite and include physical surroundings, family structure, access to motor learning experiences, and culture. Needs are related to survival, safety, motivation, psychological development, and sociocultural expectations. Together, all of these factors produce change or adaptation in the motor behaviors of the individual. Changes in growth are used as markers for development. Growth charts are familiar ways in which a child's height, weight, and head circumference are monitored during the course of development. Children can be classified as an early, an average, or a late mature according to the relationship between physiological growth parameters and chronological age. Despite the smooth trajectories seen on standard growth curves, a child's growth is not continuous but episodic. Growth is episodic at all ages with more growth occurring at night than during the day 1and 2. The effects of physical size and body proportion on motor skill acquisition or movement proficiency have been examined in adolescence but are only now being explored in younger age groups.

3.2 Factors That Affect Motor Development

There are several different factors that affect motor development, which include growth of the child. These factors include; environment, genetics, muscle tone, and gender. We'll explore each of these factors individually.

3.2.1 Child Growth

As children grow and learn, their ability to perform more activities with their body and understand actions improves. This can be affected by age and size. While most motor development skills have age-specific target ranges, the skills are also influenced by children being small or tall for their age, their weight, and their mental development.

Researchgate.net.2000.

3.2.2 Environment

The child's environment has a large effect on their motor skill development. The more opportunities they have to develop both gross and fine motor skills, the faster their capacity increases. For instance, if a child is encouraged to play outside on park equipment or other areas where they can climb, run, and play, their gross motor skills will develop quickly. Additionally, fine motor skills increase when children are encouraged to play with their hands, hold and touch smaller items, feed themselves, and draw or color.

3.2.3 Muscle Tone

As mentioned previously, muscle tone can affect motor skills. The stronger a child is, the more ability they may have to move and control their body. Muscles are a fundamental factor in a child having the strength to move their body and control their actions. If muscle development is weak, their motor skill development will be slower.

SELF-ASSESSMENT EXERCISE

i. Give the Meaning of Motor Development
ii. Define Child Growth

4.0 CONCLUSION

We begin this section with a summary and historical perspective of motor control theories. The control of human movement has been described in many different ways. The production of reflexive, automatic, adaptive, and voluntary movements and the performance of efficient, coordinated, goal-directed movement patterns involve multiple body systems (input, output, and central processing) and multiple levels within the nervous system. Each model of motor control that is discussed in this section has both merit and disadvantage in its ability to supply a comprehensive picture of motor behavior.

5.0 SUMMARY

The movement plan is customized by communications among the frontal lobes, basal ganglia, and cerebellum, with functional connections through the brain stem and thalamus. During this process specific details of the plan are determined. Postural tone, co activation, and timing of trunk muscle firing are set for proximal stability, balance, and postural control. Force, timing, and tone of limb synergies are set to allow for smooth, coordinated movements that are accurate in direction of trajectory, order, and sequence. The balance between agonist and antagonist muscle activity is determined so that fine distal movements are precise and skilled. This process is complicated by the number of possible combinations of musculoskeletal elements. The CNS must solve this “degrees of freedom” problem so that rapid execution of the goal-directed movement can proceed and reliably meet the desired outcome. Once these movement details are complete the motor plan is executed by the primary motor area in the precentral gyrus of the frontal lobe.

6.0 TUTOR – MARKED ASSIGNMENT

Explain the following terms:
1. Motor development
2. Child growth

7.0 REFERENCES/FURTHER READING

Kimble GA. 1961. Hilgard and Marquis’ Contitioning and Learning. Appleton-Century-Crofts, Inc, New York.

Squire LR, Wilted JT. 2011. The cognitive neuroscience of human memory since H.M. Annu Rev Neurosis 34: 259-288.

Squire LR. 1987. Memory and Brain. New York: Oxford Univ Press.

Schmidt RA. 1975. A schema theory of discrete motor skill learning. Psychology Rev 82: 225- 260.

Whiting HA. 1975. Concepts in Skill Learning. Lepus Book, London.

Kantak S.S, Winstein C.J. 2012. Learning-performance distinction and memory processes for motor skills: a focused review and perspective. Brain Res 228: 219-231.

Hallgató E, Győri-Dani D, Pekár J, Janacsek K, Nemeth D. 2012. The differential consolidation of perceptual and motor learning in skill acquisition. Cortex. In press.
https://www.firstdiscoverers.co.ulc/ivari-pavlov-child-development-theories/
https://online.husson.edu/consumer-behavior-pavlovian-theory/
https://incident-prevention.com/ip-articles/human-performance

https://starfishtherapies.wordpress.com/2012/10/16/motor-learning-stages-of- motor-learning-and-strategies-to-improve-acquisition-of-motor-skills/ Physical Rehabilitation: Assessment and Treatment. O'Sullivan, S. B., Schmitz, T. J. 1994. pgs 366-367.
Physical Therapy for Children. Campbell, S.K. et al. 2006. pgs. 76-90. https://incident prevention.com/ip-articles/human-performance

UNIT 2 PSYCHOLOGICAL FACTORS

CONTENTS

1.0 INTRODUCTION

Development results from the interrelated processes of maturation, physical growth, and learning and may be observed in genetic and environmental adaptation. Maturation guides development genetically in the physical changes that occur during organ differentiation in the embryo, myelination of nerve fibers, and the appearance of primary and secondary ossification centers. Growth is the process whereby changes in physical size and shape take place, as witnessed during adolescence when dramatic changes in facial and body growth occur. Adaptation, on the other hand, is the body's response to environmental stimuli. A muscle increases bulk with strength training, the immune system produces antibodies when exposed to a pathogen, bones heal after a fracture. All of these processes illustrate adaptation. Researchgate.net 2000.

2.0 OBJECTIVE

After studying this chapter, the reader will be able to:

- Define psychological factors of development.

3.0 MAIN CONTENT

3.1 Factors That Affect Motor Development

There are several different factors that affect motor development, which include growth of the child. These factors include; environment, genetics, muscle tone, and gender. We'll explore each of these factors individually.

a. Learning

It is impossible to explain behavior without reference to learning, it is the process comprehensively covering all interactions, experiences and transformations, which an individual happens to have during his lifetime, and which leave, more or less, permanent effect on him. If learning were removed from human life, a person would be helpless. Beside this, there would be no such general characteristics of social behavior such as intolerance, hate, love, shame, envy, jealousy, sympathy, etc., because these all are learnt. There are a lot of psychological definitions of learning. It's a process that brings together cognitive, emotional, and environmental influences and experiences for acquiring, enhancing, or making changes in one's knowledge, skills, values, and world views.

b. **Amount of Practice**

By repeating over and over again, the reaction becomes automatic. This is somewhat similar to the law of use and disuse. It involves principles of exercise, and of repetition or practice or drill. We learn and retain by use, and forget by disuse. Individuals learn by doing. Practice of aerobics, gymnastics, shooting, typing etc. are the obvious examples of this law. Highlighting the application of this law in physical education and sports, Charles A. Bucher has stated "the law of exercise, in respect to the development of skills in physical education, means that practice makes for better coordination, more rhythmical movement, less expenditure of energy, more skill, and better performance.

c. **Attention and Concentration**

Everything in life responds to attention. People objects, stocks of inventory, and money. Attention is the concentration of consciousness upon one object rather than upon another. It is the process of getting an object or thought clearly before the mind. It helps in bringing mental alertness and preparedness, and as a result, one becomes alert and alive, and tries to exercise one's Mental and physical power as effectively as possible.

d. Intelligence

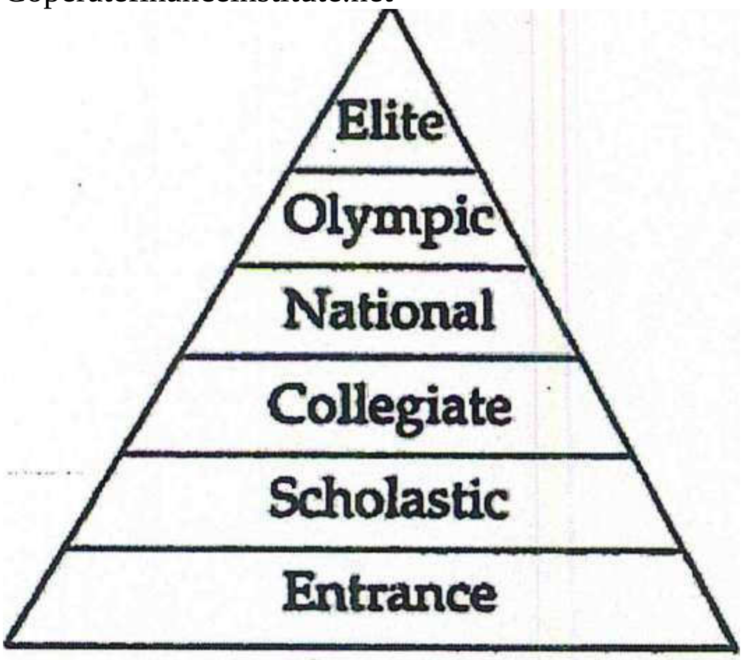
Is aggregate mental capacity or energy of an individual to act purposefully, to think rationally, and to deal effectively with one's environment. Defining intelligence in concrete terms has all through been a challenge with psychologists, philosophers and educationist over centuries probably because the list of functions, operations and activities attached to it is so exhaustive. Individuals differ from one to another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience and to engage in various forms of reasoning "Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. The relationship between physical activity and intelligence has psychologists. The nature of this relationship, however often depends on how close the physical and the intellectual elements are embedded in an activity. On this issue, Digiovanna (1937) said that intelligence is exercised in the analysis of skilled movement, the more complex and the more interpretative the movement, the greater amount of intelligence necessary to comprehend it. Intelligence in athletics also exercised in the strategy in various games. Given a series of athletic tasks, administered under the same conditions and with all other factors influencing athletic achievement to two individuals, identical in physique but differing in intellect, it is reasonable to believe that the more intellectual will prove superior. The assumption now is that intelligence plays apart in athletic achievement Intelligence of an individual plays an important role in effecting physical performance. The more complex and the more interpretative the movement, the greater the amount of intelligence necessary to comprehend. Sports activities involve complex skilled actions. Since all skilled behavior is intelligent behavior so, the relationship between sports performance and intelligence cannot be denied. Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought. Although these individual differences can be substantial, they are never entirely consistent: a given person's intellectual performance will vary on different occasions, in different domains, as judged by different criteria. Concepts of "intelligence" are attempts to clarify and organize this complex set of phenomena. Although considerable clarity has been achieved in some areas, no such conceptualization has yet answered all the important questions, and none commands universal assent. Indeed, when two dozen prominent theorists were recently asked to define intelligence, they gave two dozen, somewhat different, definitions. Intelligence has been defined in many ways: the capacity for logic, understanding, self-awareness, learning, emotional knowledge, reasoning, planning, creativity, critical thinking, and problem-solving.

3.2 Personality

Personality is the entire mental organization of a human being at any stage of his development. It embraces every phase of human character: intellect, temperament, skill, morality, and every attitude that has been built up in the course of one's life. The concept of personality is dynamic because human self is dynamic - always acting, interacting, adapting, adjusting, assimilating and integrating. This fact assumes great significance when it comes to understanding the personality development. However, it is good to remember that the relationship between sports performance and personality is far from crystal clear, it seems equally true that certain general conclusion can be drawn. Athletes differ from nonathletic on many personality traits. One research showed that athletes who participate in team and individual sports are more independent, more objective, and less anxious than non-athletes from other research it is also clear that athletes are often more intelligent than average. Generally, athletes differ from non-athletes in many personality traits. For example, it can be demonstrated that athletes are generally more independent, objective, and extraverted than non-athletes, but less anxious. Coperatefinanceinstitute.net. 2000.

Coperatefinanceinstitute.net 2000.

Coperatefinanceinstitute.net



Coperatefinanceinstitute.net

A. MOTIVATION

Motivation is the process that initiates, guides, and maintains goal-oriented behaviors. **Motivation** involves the biological, emotional, social, and cognitive forces that activate behavior. In everyday usage, the term "**motivation**" is frequently used to describe why a person does something. It is difficult to imagine anything being more important to success in motor skill learning and sport performance than motivation. In psychology, motivation refers to the initiation, direction, intensity, and persistence of behavior. Motivation is the foundation for all athletic effort and accomplishment. Without your desire and determination to improve your sports performances, all of the other mental factors, confidence, intensity, focus, and emotions, are meaningless. To become the best athlete, you must be motivated to do what it takes to maximize your ability and achieve your goals. Motivation, simply defined, is the ability to initiate and persist at a task. To perform your best, you must want to begin the process of developing as an athlete and you must be willing to maintain your efforts until you have achieved your goals. Motivation in sports is so important because you must be willing to work hard in the face of fatigue, boredom, pain, and the desire to do other things. Motivation will impact everything that influences your sports performance: physical conditioning, technical and tactical training, mental preparation, and general lifestyle include sleep, diet, school or work, and relationships. There are two primary types of motivation... Intrinsic and Extrinsic Motivation. Extrinsic Motivation is geared toward external rewards and reinforces. Extrinsic motivation may come from social sources, such as not wanting to disappoint a parent, or material rewards, such as trophies and college scholarships.

Extrinsically motivated athletes tend to focus on the competitive or performance outcome. An over-emphasis on extrinsic motivation may lead athletes to feel like their behavior is controlled by the extrinsic rewards. On the other hand, athletes may continue to feel like they control their own behavior even with the presence of extrinsic rewards. Intrinsic Motivation is geared toward internal rewards and reinforces. Intrinsically motivated athletes participate in sport for internal reasons, particularly pure enjoyment and satisfaction, and intrinsically motivated athletes typically concentrate on skill improvement and growth.

B. EMOTIONS

Emotions are our feelings. Literally, we feel them in our bodies as tingles, hot spots and muscular tension. Emotions are biologically based adaptations that assist us in responding to particular external stimuli. Wikipedia. We win a soccer match, we jump with joy, we lose a dear one, we feel sad, we see a beggar, we ~ laugh, and so on. Almost every situation evokes some feeling, and as the situation becomes intense, it is expressed as emotion. No aspect of our mental life is more important to the quality and meaning of our existence than emotions, because emotions actually express our true feelings Emotions are a response which is characterized by the Generation of energy within the body and psyche. They provide energy for us to confront challenges. Emotions play a central role in sports performance. Without being emotionally aroused an athlete's "psyching up" procedure is not complete. All winning performance is invariably a result of arousal rather than emotional upsurge in the athlete. Emotions have both facilitative and debilitative effect on athletic performance. In general, while positive emotions like joy, happiness, elation, etc., have facilitative effect on performance negative emotions such as anger, fear, anxiety, over-arousal, etc., put hurdles in the way of performance. Research on this issue is full of contradiction and still inconclusive.

However, several studies indicate that optimal emotions can initiate and maintain the required amount of effort for a task. Meaning that when, for example an athlete's anxiety level is optimal before and during competition, his or her chances of performing best are also optimal. Optimal emotions keep the athlete energized as a result of which his or her level of motivation level remains high. High arousal due either to anxiety or aggression in sports like soccer, hockey, and basketball, may result in an increase of anaerobic power, but it possibly may reduce the level of accuracy and movement precision as emotional arousal is said to blur it vision and imping upon concentration. Several studies indicate that high arousal coupled with some emotions impairs working memory. Adeyanju 1989.

C. INDIVIDUAL DIFFERENCES

Nature has not made two individuals exactly the same or even similar. People differ from one another in height, weight, color, appearance, and speed of reaction, character, personality, behavior, and the like. That people differ from each other is obvious. How and why the differ and what impact do the difference among them has on their behavior, learning ability to acquire various skills and career selection in life is less clear. This subject of individual differences is generally dealt with under individual differences in psychology or differential psychology. Psychology studies people at three levels Apart from physiological differences such as height, weight, etc., there are bound to psychological differences as well. Some athletes may be outgoing and extrovert whereas other may be shy, introvert and withdrawn, and they may also differ in their levels of perception. Some athletes are born strong psychologically while others have weak dispositions. Athletes with weak disposition fail to accomplish their task.

THORNDIKE'S LAWS OF LEARNING:

i. **Law of readiness:** speaks about learners' enthusiasm
ii. **Law of exercise:** about repetition
iii. **Law of effect:** about learners' encouragement
iv. **Law of primacy:** speaks about the opinions of the learner
v. **Law of regency:** As per this law, people often remember the most recent things they have learnt
vi. **Law of intensity:** law states that you have to develop innovative online courses in order to dive into the learners' concentration

Motor learning has been defined as a "set of internal processes associated with practice or experience leading to relatively permanent changes in the capability for skilled behavior." In other words, motor learning is when complex processes in the brain occur in response to practice or experience of a certain skill resulting in changes in the central nervous system that allow for production of a new motor skill.

SELF-ASSESSMENT EXERCISE

i. Describe the term Psychological Factors
ii. What is Personality

4.0 CONCLUSION

As children grow and learn, their ability to perform more activities with their body and understand actions improves. This can be affected by age and size. While most motor development skills have age-specific target ranges, the skills are also influenced by children being small or tall for their age, their weight, and their mental development.

We begin this section with a summary and historical perspective of motor control theories. The control of human movement has been described in many different ways. The production of reflexive, automatic, adaptive, and voluntary movements and the performance of efficient, coordinated, goal-directed movement patterns involve multiple body systems (input, output, and central processing) and multiple levels within the nervous system.

5.0 SUMMARY

Personality is the entire mental organization of a human being at any stage of his development. It embraces every phase of human character: intellect, temperament, skill, morality, and every attitude that has been built up in the course of one's life. The concept of personality is dynamic because human self is dynamic - always acting, interacting, adapting, adjusting, assimilating and integrating. This fact assumes great significance when it comes to understanding the personality development. The movement plan is customized by communications among the frontal lobes, basal ganglia, and cerebellum, with functional connections through the brain stem and thalamus. During this process specific details of the plan are determined. Postural tone, co activation, and timing of trunk muscle firing are set for proximal stability, balance, and postural control. Force, timing, and tone of limb synergies are set to allow for smooth, coordinated movements that are accurate in direction of trajectory, order, and sequence. The balance between agonist and antagonist muscle activity is determined so that fine distal movements are precise and skilled. This process is complicated by the number of possible combinations of musculoskeletal elements. The CNS must solve this “degrees of freedom” problem so that rapid execution of the goal-directed movement can proceed and reliably meet the desired outcome. Once these movement details are complete the motor plan is executed by the primary motor area in the precentral gyrus of the frontal lobe.

6.0 TUTOR – MARKED ASSIGNMENT

Explain the following terms:

1. Personality
2. Learning
3. Intelligent

7.0 REFERENCES/FURTHER READING

Kimble GA. 1961. Hilgard and Marquis’ Contitioning and Learning. Appleton-Century-Crofts, Inc, New York.

Squire LR, Wilted JT. 2011. The cognitive neuroscience of human memory since H.M. Annu Rev Neurosis 34: 259-288.

Squire LR. 1987. Memory and Brain. New York: Oxford Univ Press.

Schmidt RA. 1975. A schema theory of discrete motor skill learning. Psychology Rev 82: 225- 260.

Whiting HA. 1975. Concepts in Skill Learning. Lepus Book, London.

Kantak S.S, Winstein C.J. 2012. Learning-performance distinction and memory processes for motor skills: a focused review and perspective. Brain Res 228: 219-231.

Hallgató E, Győri-Dani D, Pekár J, Janacsek K, Nemeth D. 2012. The

differential consolidation of perceptual and motor learning in skill acquisition. Cortex. In press.
https://www.firstdiscoverers.co.ulc/ivari-pavlov-child-development-theories/
https://online.husson.edu/consumer-behavior-pavlovian-theory/
https://incident-prevention.com/ip-articles/human-performance

https://starfishtherapies.wordpress.com/2012/10/16/motor-learning-stages-of- motor-learning-and-strategies-to-improve-acquisition-of-motor-skills/ Physical Rehabilitation: Assessment and Treatment. O'Sullivan, S. B., Schmitz, T. J. 1994. pgs 366-367. Physical Therapy for Children. Campbell, S.K. et al. 2006. pgs. 76-90. https://incident prevention.com/ip-articles/human-performance

MODULE 3

UNIT 1 MOTOR CONTROL

CONTENTS

1.0 INTRODUCTION

Motor control theories provide a framework for interpreting movement and behavior. Motor control is the ability to organize and control functional movement. The field of motor control grew primarily from the specialized study of neurophysiology in an attempt to explain how functional movement is produced and regulated in humans. From a historical perspective, several different theories and models have been proposed. Some models approach motor control from a physiological perspective, and others have a psychological perspective. Regardless, it is important to realize that these theories are ever changing and evolving based on contemporary thought and the current research. When the explanations of an existing theory are no longer sufficient to interpret the research data, new theories are developed. Living beings and man, in particular, continuously influence their environment and adapt to varying situations. Adaptation is an active function and critical for survival (and reproduction), and often involves learning, traditionally defined as a relatively permanent change in a behavior potentiality that occurs as a result of reinforced practice1), and the flexible control over and execution of what has been learned. Among the important functions for interacting with the environment are movement and actions. There is strong evidence that the learning and control of such motor skills constitutes a specific domain of competence. Thus, changes in motor behavior (motor learning) usually require practice and often last longer than newly acquired declarative knowledge and memories. For example, once an individual has learned to ride a bicycle, he or she usually maintains this motor skill over many years without further practice.

2.0 OBJECTIVES

After studying this chapter, the reader will be able to:

- Define motor control and motor learning.
- Explain Skills Behaviour.
- Practice.
- Models of Motor Control

3.0 MAIN CONTENT

3.1 Definition of Motor Control and Motor Learning

Motor - in physical education and studies of the body this refers to movement. ... Motor learning refers to the brain's ability to develop control over the body' muscular skeletal system to produce coordinated and timed movements in response to the demands of the surrounding environment. Motor control is a complex process occurring in the brain in response to practice or experience of a certain skill resulting in changes in the central nervous system. It allows for the production of a new motor skill. ... Motor control requires practice, feedback and knowledge of results. Motor control involves learning a skilled task and then practising with a goal in mind until the skill is executed automatically (Schmidt & Wrisberg 2007). For example, learning to play a song on the piano initially takes a lot of thought and practise before the task is automatic and executed skilfully. In a book entitled Human Performance, the well-known psychologists proposed three stages of learning motor skills: a cognitive phase, an associative phase, and an autonomous phase. During the twentieth century, scholars attempted to explain the mechanisms of motor control. Initially, it was thought that the brain organized movement through reflexes alone or as a hierarchy. Later models were developed that described feedback and programming within the nervous system. A systems model is the most contemporary model of motor control at this time. Motor control is the ability to organize and control functional movement. Each of these models is discussed in turn.

3.2 Skill Behaviour

There are several concepts which play a key role in this theory. One such concept is skill. The definition of skill is vague. As defined by Vanpatten & Benati (2010) "Skill refers to ability to do rather than underlying competence or mental representation". To clarify this concept, Cornford (1996) has mentioned nine separate defining attributes of "skill" and "skilled performance" from a psychological perspective, argued to be the most valid in accounting for skill acquisition and performance by individuals. These defining attributes are:

1. Skill is learned;
2. Skill involves motivation, purpose and goals;
3. Schemas are prerequisite for skilled performance;
4. Skills require content and context knowledge;
5. Skills are performed and transferred in the presence of specific stimuli;
6. Skills involve problem solving relevant to the context.
7. Skill involves relative judgments with individual differences in skilled performance evident.
8. Standards of excellence are important;
9. Skill involves comparable replication;
10. Considerable periods of time are required to reach high levels of skill.

The other important concept in Skill Acquisition Theory is "priming" which, according to Trofimovich & McDonough (2013), "refers to a cognitive repetition phenomenon in which prior exposure to specific language forms or meaning facilitates speaker's subsequent language processing". For example, a words or structure used by a speaker will influence the comprehension and production of that word or structure by the interlocutor. Therefore, it "may underlie the interactive, communicative use of language" (Trofimovich & McDonough). At the same time, it can be categorized under the implicit learning since it often happens with little awareness and conscious effort on the part of language user (Trofimovich & McDonough).

Automaticity The other concept within this theory is automaticity. According to DeKeyser (2007), in skill acquisition models, the learning processes which are involved in the acquisition of skills entails a transition from attentive to automatic mode. Hulstijn (2002) believes that performance fluency is the outcome of implicit learning, and a concomitant, incidental feature of implicit learning is automatization. But defining auto maximization is not an easy task. As mentioned by Dekeyser (2007), "In the broadest sense, it refers to the whole process of knowledge change from initial presentation of the rule in declarative format to the final stage of fully spontaneous, effortless, fast, and errorless use of that rule, often without being aware of it anymore. In a narrower sense, it refers to the slow process of reducing error rate, reaction time, and interference with/from other tasks that takes place after proceduralization. In the most specific sense, it designates a merely quantitative change in the subcomponents of procedural knowledge to the exclusion of any qualitative change or restructuring (i.e., excluding changes in which small subcomponents make up procedural knowledge at a given stage of skill development or how they work together)." In fact, as acknowledged by Cohen, Servan-Schreiber, & McClelland (1992), the term automaticity embodies some different phenomena that often differ from one definition to another. Nevertheless, the following core set of phenomena seem to reappear in most discussions of automaticity: -

- An increase in speed of performance with practice following a power law diminishing requirements for attention with practice, with a commitment release from attentional control - or involuntariness (i.e., the involuntariness of automatic processes) immunity from interference with competing processes, and the requirement that practice be “consistently mapped” for these phenomena to develop. It should be mentioned that DeKeyser (2007) has chosen the term automatized knowledge to refer to the knowledge which may still be conscious but the learner has access to it in actual communication. In Dekeyser's view, automaticity rather than being an all-or-nothing issue has degrees.

3.3 Practice

According to DeKeyser (2007), among researchers who study skill acquisition processes there is a consensus that practice with a given task gradually decreases reaction time and error rate. Carlson (1997, as cited in DeKeyser, 2007) has defined practice as “repeated performance of the same (or closely similar) routines”. As it can be observed, this definition is fairly vague and seems to reflect behavioristic views rather than those of cognitive psychology. DeKeyser (2007) believes this is not what Carlson means. Therefore, he has found the definition by Newell and Rosenbloom (1981, as cited in DeKeyser, 2007) to be more precise, i.e., “Practice is the subclass of learning that deals only with improving performance on a task that can already be successfully performed”. Practice which is required for learning in skill Acquisition Theory, according to Dekeyser (2007) should be meaningful. In fact, Dekeyser has questioned the utility of mechanical drills by considering them to provide just language-like behavior rather than language behavior.

Power law of practice Newell & Rosenbloom (1981) have studied practice and its following performance improvements both theoretically and experimentally. On the theoretical side, they have formulated 'chunking theory of learning' which is rooted in cognitive psychology. And on experimental side, they have argued that a single law, i.e., the "log-log linear learning law" or the "power law of practice" describes all of the practice data. According to Newell & Rosenbloom, this ubiquitous quantitative law of practice, states "plotting the logarithm of the time to perform a task against the logarithm of the trial number always yields a straight line, more or less". Hulstijn (2002) believes that auto matization conforms to the power law of learning both in what Gupta & Dell (1999) name "repetition priming" and "skill learning". The former occurs when we process identical stimuli over and over again (i.e., the same word is processed the many times), whereas the latter occurs when we process stimuli which (1) vary in some respect at the surface, but (2) share similarities or regularities at an underlying level of structure. D. Theories Spellman (2005) believes that there are two groups of theories regarding skill acquisition. The first group holds that skill acquisition results from a process of strategy refinement. This is the idea underlying the theories of Crossman, Anderson (ACT-R), Newell et al. (SOAR), MacKay, and some connectionist theories. And the other group holds that skilled performance is the results of improved memory retrieval. This idea can be found in the theories of Logan (Instance theory) and Palmeri (EBRW).

Adaptive control of thought model (ACT) According to Vanpatten & Benati (2010), Adaptive Control of Thought (ACT) model, developed by John Anderson, is the most well-known models of skill-based theories. Anderson (1982) proposed a framework for skill acquisition including two major stages in the development of a cognitive skill, i.e., declarative and procedural stage. In this framework "facts are encoded in a propositional network and procedures are encoded as productions" (Anderson, 1982). According to Vanpatten & Benati (2010), "Within this theory, development involves the use of declarative knowledge followed by procedural knowledge, with the latter‟s automatization." Therefore, SLA is conceived to be a progression through three stages, declarative, procedural, and autonomous. These three stages resemble the three stages of cognitive, associative, and autonomous stage which Fitts (1964, as cited in Taatgen, 2002) posits for skill acquisition. Taatgen (2002) has linked Anderson and Fitts stages by saying "In the cognitive stage knowledge is declarative and needs to be interpreted. Interpreting knowledge is slow, and may lead to errors if the relevant knowledge cannot be retrieved at the right time. Procedural knowledge on the other hand is compiled and therefore fast and free of errors, and can be associated with the autonomous stage. The associate stage is an in-between stage, during which part of the knowledge is declarative and another part compiled.

Prevention programs at work

Prevention programs can be divided into primary and secondary prevention programs. Primary prevention focuses on reducing the incidence of new episodes of injury. Primary prevention programs aim to assist the worker by increasing his or her resistance to musculoskeletal injury (proper lifting techniques, material handling, behavior modification) or to improve the work by reducing the physical demands, usually through the ergonomic redesign of tasks and work spaces.

Secondary prevention programs are designed primarily to reduce disability or work absenteeism for people who already have a problem; the programs are categorized as work place-based interventions and health system interventions. Work place prevention programs include an active physician or therapist at work who is involved with instructing workers immediately after a muscular skeletal injury and modifying duties at work. In the secondary prevention programs of the health system, health care givers who diagnose and treat workers are required mainly to minimize pain and disability, and structure rehabilitation programs. Prevention programs vary from place to place, yet, most back injury prevention programs include:

(1) Back belts,
(2) Exercise/flexibility training,
(3) Back schools, and
(4) Educational classes.

These programs may include combinations of education in: back pain/injury prevention, wearing the belt, fitness body mechanics, lifting ergonomics, and structure and function of spine; demonstration and practice of body mechanism and basic exercises; training in injury prevention methods; ergonomic improvements; pain control relaxation; and supervised practice sessions with individual feedback. Despite the existence of some evidence about the efficacy of prevention programs, there is uncertainty and even disagreement among health professional about the outcome of intervention programs for people with MSD. Most programs for exercise/flexibility training and back schools were found to have positive effects whereas, evidence supporting the use of back braces and back belt programs and education programs in industry is conflicting. Carlton found that there was no carryover of the information learned regarding proper body mechanics to the actual work site. Furthermore, Frank et al. reported that in some places where secondary prevention program was offered at the workplace, the workers perceived these programs as pressure for premature return to work. Indeed, very few interventions have produced a clear reduction in the incidence of musculoskeletal injuries when evaluated by rigorous scientific criteria. Moreover, despite intervention attempts, the overall trend for work related injuries has been relatively stable over the past several decades, or on the rise as claimed by some. Minimal progress in reduction may be due to lack of etiologic understanding, lack of appropriate intervention selection, or lack of appropriate intervention implementation. Turner, argues that when researching prevention programs, the length of time of follow up is critical. She claims that workers who attended back school programs do show significantly fewer sick-leave days during their initial pain episode than those in a placebo treatment. However, there were no differences between back school, physiotherapy, and placebo groups on measures of pain, function or recurrence of pain during follow up a year later. Her findings concur with other researchers who found that prevention programs were less effective during follow-up. From the above discussion it is apparent that primary and secondary work prevention programs are limited in their effectiveness. In an attempt to rectify this situation, it is proposed that principles of motor learning can assist the therapist in structuring prevention programs, in order to facilitate workers learning of correct movement patterns. Motor control is defined as “the systematic transmission of nerve impulses from the motor cortex to motor units, resulting in coordinated contractions of muscles.

This definition describes motor control in the simplest terms—as a top-down direction of action through the nervous system. In reality, the process of controlling movement begins before the plan is executed, and ends after the muscles have contracted. The essential details of a movement plan must be determined by the individual before the actual execution of the plan. The nervous system actively adjusts muscle force, timing, and tone before the muscles begin to contract, continues to make adjustments throughout the motor action, and compares movement performance with the goal and neural code (directions) of the initial motor plan. This extension of the definition takes into account that the body accesses sensory information from the environment, perceives the situation and chooses a movement plan that it believes to be the appropriate plan to meet the outcome goal of the task that the person is attempting to complete, coordinates this plan within the CNS, and finally *executes* the plan through motor neurons in the brain stem and spinal cord to communicate with muscles in postural and limb synergies, plus muscles in the head and neck that are timed to fire in a specific manner. The movement that is produced supplies sensory feedback to the CNS to allow the person to (1) modify the plan during performance, (2) know whether the goal of the task has been achieved, and (3) store the information for future performance of the same task-goal combination. Repeated performance of the same movement plan tends to create a preferred pattern that becomes more automatic in nature and less variable in performance. If this movement pattern is designed and executed well, then it is determined that the person has developed a skill. If this pattern is incorrect and does not efficiently accomplish the movement goal, then it is considered abnormal.

3.4 Models of Motor Control

We begin this section with a summary and historical perspective of motor control theories. The control of human movement has been described in many different ways. The production of reflexive, automatic, adaptive, and voluntary movements and the performance of efficient, coordinated, goal-directed movement patterns involve multiple body systems (input, output, and central processing) and multiple levels within the nervous system. Each model of motor control that is discussed in this section has both merit and disadvantage in its ability to supply a comprehensive picture of motor behavior. These theories serve as a basis for predicting motor responses during patient examination and treatment. They help explain motor skill performance, potential, constraints, limitations, and deficits.

They allow the clinician to (1) identify problems in motor performance, (2) develop treatment strategies to help clients remediate performance problems, and (3) evaluate the effectiveness of intervention strategies employed in the clinic. Selecting and using an appropriate model of motor control is important for the analysis and treatment of clients with dysfunctions of posture and movement. As long as the environment and task demands affect changes in the CNS and the individual has the desire to learn, the adaptable nervous system will continue to learn, modify, and adapt motor plans throughout life.

Motor programs and central pattern generators

A motor program (MP) is a learned behavioral pattern defined as a neural network that can produce rhythmic output patterns with or without sensory input or central control. MPs are sets of movement commands, or “rules,” that define the details of skilled motor actions. An MP defines the specific muscles that are needed, the order of muscle activation, and the force, timing, sequence, and duration of muscle contractions. MPs help control the degrees of freedom of interacting body structures, and the number of ways each individual component acts. A generalized motor program (GMP) defines a pattern of movement, rather than every individual aspect of a movement. GMPs allow for the adjustment, flexibility, and adaptation of movement features according to environmental demands. The existence of MPs and GMPs is a generally accepted concept; however, hard evidence that an MP or a GMP exists has yet to be found. Advancements in brain imaging techniques may substantiate this theory in the future. In contrast to MPs, a central pattern generator (CPG) is a genetically predetermined movement pattern. CPGs exist as neural networks within the CNS and have the capability of producing rhythmic, patterned outputs resembling normal movement. These movements have the capability of occurring without sensory feedback inputs or descending motor inputs. Two characteristic signs of CPGs are that they result in the repetition of movements in a rhythmic manner and that the system returns to its starting condition when the process ceases. Both MPs and CPGs contribute to the development, refinement, production, and recovery of motor control throughout life.

Motor control evolves so that people can cope with the environment around them. A person must focus on detecting information in the immediate environment (perception) that is determined to be necessary for performance of the task and achievement of the desired outcome goal. The individual is an active observer and explorer of the environment, which allows the development of multiple ways in which to accomplish (choose and execute) any given task. The individual analyses a particular sensory environment and chooses the most suitable and efficient way to complete the task. The *person* consists of all functional and dysfunctional body structures and functions that exist and interact with one another. The *task* is the goal-directed behavior, challenge, or problem to be solved. The *environment* consists of everything outside of the body that exists, or is perceived to exist, in the external world. All three of these motor control constructs (person, task, environment) are dynamic and variable, and they interact with one another during learning and production of a goal-directed, effective motor plan.

Body Structures and Functions That Contribute to The Control of Human Posture and Movement

Keen observation of motor output quality during the performance of functional movement patterns helps the therapist determine activity limitations and begin to hypothesize impairments within sensory, motor, musculoskeletal, cardiopulmonary, and other body systems. The following section presents and defines some of these key factors, including sensory input systems, motor output systems, and structures and functions involved in the integration of information in the CNS.

Role of sensory information in motor control

Sensory receptors from somatosensory (exteroceptors and proprioceptors), visual, and vestibular systems and taste, smell, and hearing fire in response to interaction with the external environment and to movement created by the body. Information about these various modalities is transmitted along afferent peripheral nerves to cells in the spinal cord and brain stem of the CNS. All sensory tracts, with the exception of smell, then synapse in respective sensory nuclei of the thalamus, which acts as a filter and relays this information to the appropriate lobe of the cerebral cortex (e.g., somatosensory to parietal lobe, visual to occipital lobe, vestibular, hearing, and taste to temporal lobe). Sensory information is first received and perceived, then associated with other sensory modalities and memory in the association cortex. Once multiple sensory inputs are associated with one another, the person is then able to *perceive* the body, its posture and movement, the environment and its challenges, and the interaction and position of the body with objects within the environment. The person uses this perceptual information to create an internal representation of the body (internal model) and to choose a movement program, driven by motivation and desire, to meet a final outcome goal. Although the sensory input and motor output systems operate differently, they are inseparable in function within the healthy nervous system. Agility, dexterity, and the ability to produce movement plans that are adaptable to environmental demands reflect the accuracy, flexibility, and plasticity of the sensory-motor system.

The CNS uses sensory information in a variety of ways to regulate posture and movement. Before movement is initiated, information about the position of the body in space, body parts in relation to one another, and environmental conditions is obtained from multiple sensory systems. Special senses of vision, vestibular inputs that respond to gravity and movement, and visual-vestibular interactions supply additional information necessary for static and dynamic balance and postural control as well as visual tracking. Auditory information is integrated with other sensory inputs and plays an important role in the timing of motor responses with environmental signals, reaction time, response latency, and comprehension of spoken word. This information is integrated and used in the selection and execution of the movement strategy. During movement performance, the cerebellum and other neural centres use feedback to compare the actual motor behavior with the intended motor plan. If the actual and intended motor behaviors do not match, an error signal is produced and alterations in the motor behavior are triggered. In some instances, the control system anticipates and makes corrective changes before the detection of the error signal. This anticipatory correction is termed *feed-forward control.* Changing one's gait path while walking in a busy shopping mall to avoid a collision is an example of how visual information about the location of people and objects can be used in a feed-forward manner.

Another role of sensory information is to revise the reference of correctness (central representation) of the MP before it is executed again. For example, a young child standing on a balance beam with the feet close together falls off of the beam. An error signal occurs because of the mismatch between the intended motor behavior and the actual motor result. If the child knows that the feet were too close together when the fall occurred, then the child will space the feet farther apart on the next trial. The information about what happened, falling or not falling, is used in planning movement strategies for balancing on any narrow object such as a balance beam, log, or wall in the future. Sensory information is necessary during the acquisition phase of learning a new motor skill and is useful for controlling movements during the execution of the motor plan. However, sensory information is not always necessary when performing well-learned motor behaviors in a stable and familiar context. Rothwell and colleagues studied a man with severe sensory neuropathy in the upper extremity. He could write sentences with his eyes closed and drive a car with a manual transmission without watching the gear shift. He did, however, have difficulty with fine motor tasks such as buttoning his shirt and using a knife and fork to eat when denied visual information. The importance of sensory information must be weighed by the individual, unconsciously filtering and choosing appropriate and accurate sensory inputs to use to meet the movement goal.

Sensory experiences and learning alter sensory representations, or cortical "maps," in the primary somatosensory, visual, and auditory areas of the brain. Training, as well as use and disuse of sensory information, has the potential to drive long-term structural changes in the CNS, including the formation, removal, and remodelling of synapses and dendritic connections in the cortex. This process of cortical plasticity is complex and involves multiple cellular and synaptic mechanisms.

SELF – ASSESSMENT EXERCISE

i. Define motor control and motor learning.
ii. Explain Skills Behaviour.
iii. Practice.
iv. Models of Motor Control

4.0 CONCLUSION

This selective review has shown that cognitive neuroscientific studies have contributed considerably to resolving controversial and unclear issues related to motor learning and motor control. This does not only concern the elucidation of the underlying neuroanatomical systems but – more importantly – the mechanisms implemented in these systems. Therefore, imaging and ERP studies have already proven to be valuable tools for deepening our understanding of motor learning and control. As these approaches are adapted to increasingly naturalistic situations, considerable progress can be expected in the understanding of motor learning and control, and in the application of this knowledge in sports science, motor rehabilitation, and educational fields.

5.0 SUMMARY

Motor control theories provide a framework for interpreting movement and behavior. Motor control is the ability to organize and control functional movement. The field of motor control grew primarily from the specialized study of neurophysiology in an attempt to explain how functional movement is produced and regulated in humans. From a historical perspective, several different theories and models have been proposed. Some models approach motor control from a physiological perspective, and others have a psychological perspective.

6.0 TUTOR – MARKED ASSIGNMENT

1. Define motor control and motor learning.
2. Explain Skills Behaviour.
3. Practice.
4. Models of Motor Control.

7.0 REFERENCES/FURTHER READING

Kimble G.A. (1961). Hilgard and Marquis' Conditioning and Learning. Appleton-Century- Crofts, Inc, New York.

Squire LR, Wixted JT. (2011). The cognitive neuroscience of human memory since H.M. Annu Rev Neurosci 34: 259-288.

Squire L.R. (1987). Memory and Brain. New York: Oxford Univ Press. Schmidt R.A. (1975). A schema theory of discrete motor skill learning. Psychol Rev 82: 225-260.

Whiting H.A. (1975). Concepts in Skill Learning. Lepus Book, London.

Kantak S.S, Winstein C.J. (2012). Learning-performance distinction and memory processes for motor skills: a focused review and perspective. Behav Brain Res 228: 219-231.

Hallgató E, Győri-Dani D, Pekár J, Janacsek K, Nemeth D. (2012). The differential consolidation of perceptual and motor learning in skill acquisition. Cortex. In press.

Adams J.A. (1971). A closed-loop theory of motor learning. J Mot Behav 3: 111-150.

Keele S.W. (1968). Movement control in skilled motor performance. Psychol Bull 70: 387-403.

Breedlove S.M, Watson N.V, Rosenzweig M.R. (2010). Biological Psychology: An Introduction to Behavioral, Cognitive, and Clinical Neuroscience. Sinauer Associates Inc., Sunderland, MA, USA.

UNIT 2 THEORIES OF MOTOR CONTROL

CONTENTS

1.0 INTRODUCTION

Motor control theories provide a framework for interpreting movement and behavior. Motor control is the ability to organize and control functional movement. The field of motor control grew primarily from the specialized study of neurophysiology in an attempt to explain how functional movement is produced and regulated in humans. From a historical perspective, several different theories and models have been proposed. Some models approach motor control from a physiological perspective, and others have a psychological perspective. Regardless, it is important to realize that these theories are ever changing and evolving based on contemporary thought and the current research. When the explanations of an existing theory are no longer sufficient to interpret the research data, new theories are developed. Living beings and man, in particular, continuously influence their environment and adapt to varying situations. Adaptation is an active function and critical for survival (and reproduction), and often involves learning, traditionally defined as a relatively permanent change in a behavior potentiality that occurs as a result of reinforced practice1), and the flexible control over and execution of what has been learned. Among the important functions for interacting with the environment are movement and actions. There is strong evidence that the learning and control of such motor skills constitutes a specific domain of competence. Thus, changes in motor behavior (motor learning) usually require practice and often last longer than newly acquired declarative knowledge and memories. For example, once an individual has learned to ride a bicycle, he or she usually maintains this motor skill over many years without further practice.

2.0 OBJECTIVE

After studying this chapter, the reader will be able to:

- Discuss the basic theories of motor control and motor learning.

3.0 MAIN CONTENT

3.1 Motor Control Theories

The major theories of motor control are described, which include, motor programming theory, systems theory, the theory of dynamic action, and the theory of parallel distributed processing, as well as the factors that influence motor learning and its applications in neuro rehabilitation. Motor control theory emphasizes that skills are acquired using specific strategies and are refined through a great deal of repetition and the transfer of skills to other tasks (Croce & De Paepe, 1989). Exner and Henderson (1995) provide an overview of motor control relative to hand skills in children.

Early perspectives of motor control date back to the late 1800s, when two similar views were proposed that pointed to a hierarchical organization. In separate research, the authors claimed that sensory input was necessary for the control of motor output. James suggested that a successive chain of muscular contractions inherent in a habitual motor act were triggered in sequence by associated sensations, or chaining. By the turn of the century, Sharon, proposed his reflex model, wherein a sequence of reflexes formed the building blocks of complex motor behavior. Unfortunately, these two related theories did not explain movement that occurs without a sensory stimulus, nor did they explain how actions are modified depending on the context in which they occur (e.g., varying speed, novel conditions). As a framework for the present review, some important concepts and models of motor control and learning will first be explained. One should distinguish between motor control of slow and rapid movements. When relatively slow movements are to be executed, one can use proprioceptive and visual feedback information in order to achieve the predetermined results by correcting any discrepancies between the attempted and achieved movement. The closed-loop theory8) emphasizes the importance of the perceptual trace, that is, the representation of an attempted movement. When there is a discrepancy between the perceptual trace and feedback information about an ongoing movement, an error signal will be sent to the motor control system allowing for an appropriate correction of the ongoing movement. Closed-loop control occurs only when feedback information can be used, and therefore does not operate for purely ballistic movements (see below). Examples of closed-loop movements are figure skaters making near perfect circles while keeping their balance or car drivers performing a turn, precisely adjusting steering directing and driving speed. In contrast to slow movements under closed-loop control, ballistic movements are thought to be controlled by motor programs that are independent of feedback, which is referred to as open-loop control. Keele (1968) formally defined a motor program as “a set of muscle commands that are structured before a movement sequence begins, and that allows the entire sequence to be carried out uninfluenced by peripheral feedback. Thus, performers of ballistic movements cannot use proprioceptive feedback to evaluate and modify their ongoing movement before it is completed. For example, hard punches in boxing and batting in baseball are primarily controlled by motor programs and cannot be altered during their execution by means of proprioceptive or visual feedback. Hence, learning ballistic movements can only rely on the information returned after movement completion, whereas for no ballistic skill acquisition closed-loop control can be used to evaluate success even during the movement. Motor Control Theories include the production of reflexive, automatic, adaptive, and voluntary movements and the performance of efficient, coordinated, goal-directed movement patterns which involve multiple body systems (input, output, and central processing) and multiple levels within the nervous system.

In order to initiate a movement according to the closed loop theory), one has to retrieve the intended action1 from previous experience (i.e., memory trace). This theory suggests that one must have stored representations of many different movements. However, this idea poses two problems. First, if every conceivable motor experience was stored in memory, storage capacity would soon be exceeded (storage problem). Second, contrary to a prediction of the closed-loop theory, subjects can perform even novel skilled movements relatively well on the first occasion (novelty problem). To overcome the storage and novelty problems, Schmidt proposed the so-called schema theory). According to this theory, only abstract forms of movements can be stored in memory (i.e., a schema or rule). In addition, we seem to use generalized motor programs (GMPs) that regulate similar kinds of movements, belonging to the same motor class determined by the invariant characteristics of actions (e.g., throwing a ball and spiking a ball in volleyball share similar motor properties). A GMP contains an abstract representation about the temporal structure of events (i.e., phasing), the relative force, and the sequence of events that is needed to produce the action. Like a mathematical formula a schema represents the relationship between internal motor parameters and movement outcome. To determine this relationship, only a few experiences of performing the movement may be sufficient. Once an individual has constructed a recall schema, they can inversely determine specific parameters to be applied to the GMP. Thus they can easily succeed in throwing a ball at a target located at a distance that they have never aimed at before, by determining a specific force parameter from the recall schema and applying it to the GMP associated with the throwing movement. According to the schema theory, the recall schema dominates in ballistic movements. For slower movements the recognition schema is more important. The recognition schema represents the relationship between sensory consequences and movement outcomes. By means of the recognition schema one's own movement can be evaluated). The schema theory and closed-loop theory make different predictions for the optimal practice schedule of a novel movement. The closed-loop theory suggests that the repetition of the same movement is essential to learn a skill, strengthening the perceptual trace; this idea seems to fit an individual's daily experience. However, the schema theory predicts better performance after practicing several different, but related motor tasks, and variations of a task, even with fewer trial numbers than repeatedly practicing the same task. In a test of these predictions, Shea and Kohl (1991) examined the learning effects for four practice conditions in a target force production task (20 blocks consisting of five test trials: 150 N, Experiment). In the specific + space condition, the learners practiced only the test trials (150 N exertion, 100 test trials in total) with 16-s intervals between trials (inter trial interval: ITI). In the specific + specific condition, the learners performed three additional test trials during the ITI, resulting in 4-s intervals between trials (340 test trials in total). In the specific + variable condition, the learners exerted three trials during the ITI, but the target forces were 25 or 50 N above or below the target force on test trials (i.e., 100, 125, 175, and 200 N). In the specific + alternative condition, the learners performed a tracking task during the middle 12s of the ITI. Poorer performance (i.e., larger errors) was found in the specific + variable condition than in the other conditions during the acquisition phase. However, on a retention test on the next day, the specific + variable condition showed the best performance, whereas the specific + specific condition was worst (the two other conditions showed intermediate results). Similar results were also found in Experiment), and these results were consistent with their previous study). This inversion of performance, between training and retention test, supports the predictions of the schema theory. This theory is not properly explained to bring out a meaning.

There are many methods for studying neural mechanisms of motor learning and motor control, such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET), recordings of the electromyogram (EMG), electro enphalogram (EEG), and event related brain potentials (ERPs), transcranial magnetic stimulation (TMS), and the elicitation of reflexes. Because of their relative ease and noninvasiveness, excellent time resolution, relative mobility, and inexpensiveness, ERPs are of special importance. Therefore, we (who)? will introduce this technique in some detail. ERPs are derived from EEG recordings by averaging selected time epochs synchronized to an event, for example, to a stimulus, muscle activation, or a button press. The average signal derived by this process consists of a complex waveform with positive and negative deflections during certain time intervals and with a specific voltage distribution across the head surface. Using such characteristics, so-called components can be defined; and in many cases they can be related to putative cognitive sub processes that take place in specific brain systems. Some of these components are of special interest for motor control and motor learning. Make the subtitle understandable to the readers.

Motor control evolves so that people can cope with the environment around them. A person must focus on detecting information in the immediate environment (perception) that is determined to be necessary for performance of the task and achievement of the desired outcome goal. The individual is an active observer and explorer of the environment, which allows the development of multiple ways in which to accomplish (choose and execute) any given task. The individual analyses a particular sensory environment and chooses the most suitable and efficient way to complete the task. The *person* consists of all functional and dysfunctional body structures and functions that exist and interact with one another. The *task* is the goal-directed behavior, challenge, or problem to be solved. The *environment* consists of everything outside of the body that exists, or is perceived to exist, in the external world. All three of these motor control constructs (person, task, environment) are dynamic and variable, and they interact with one another during learning and production of a goal-directed, effective motor plan.

3.2 Choice of Motor Pattern and The Control of Voluntary Movement

A choice of body movement is made based on the person's perception of the environment, his or her relationship to objects within it, and a goal to be met. The person chooses from a collection of plans that have been developed and refined over his or her lifetime. If a movement plan does not exist, a similar plan is chosen and modified to meet the needs of the task. Once the plan has been chosen it is customized by the CNS with what are determined to be the correct actions to execute given the perceived situation and goal of the individual under the following:

A. Coordination

The movement plan is customized by communications among the frontal lobes, basal ganglia, and cerebellum, with functional connections through the brain stem and thalamus. During this process specific details of the plan are determined. Postural tone, co active, and timing of trunk muscle firing are set for proximal stability, balance, and postural control. Force, timing, and tone of limb synergies are set to allow for smooth, coordinated movements that are accurate in direction of trajectory, order, and sequence. The balance between agonist and antagonist muscle activity is determined so that fine distal movements are precise and skilled. This process is complicated by the number of possible combinations of musculoskeletal elements. The CNS must solve this “degrees of freedom” problem so that rapid execution of the goal-directed movement can proceed and reliably meet the desired outcome. Once these movement details are complete the motor plan is executed by the primary motor area in the precentral gyrus of the frontal lobe.

B. Execution

Pyramidal cells in the corticospinal and corticobulbar tracts *execute* the voluntary motor plan. Neural impulses travel down these central efferent systems and communicate with motor neurons in the brain stem and spinal cord. The corticobulbar tract communicates with brain stem motor nuclei to control muscles of facial expression, mouth and tongue for speaking and eating, larynx and pharynx for voice and swallow, voluntary eye movements for visual tracking and saccades, and muscles of the upper trapezius for shoulder girdle elevation. The corticospinal tract communicates with motor neurons in the spinal cord. The ventral corticospinal tract system communicates primarily with proximal muscle groups to provide the appropriate amount of activation to stabilize the trunk and limb girdles, thus allowing for dexterous distal limb movements. The lateral corticospinal tract system communicates primarily with muscles of the arms and legs—firing alpha motor neurons in coordinated synergy patterns with appropriate activity in agonist and antagonist muscles so that movements are smooth and precise. Other motor nuclei in the brain stem are programmed to fire just before corticospinal tract activity in order to supply postural tone. These include lateral and medial vestibular spinal tracts, reticulospinal tract, and rubrospinal tract systems. Adequate and balanced muscle tone of flexors and extensors in the trunk and limbs occurs automatically, without the need for conscious control. These brain stem nuclei have tonic firing rates that are modulated up or down to effectively provide more or less muscle tone in body areas depending on stimulation from gravity, limbic system activity, external perturbations, or other neuronal activity.

C. Adaptation

Adaptation is the process of using sensory inputs from multiple systems to adapt motor plans, decrease performance errors, and predict or estimate consequences of movement choices. The goal of adaptation is the production of consistently effective and efficient skilled motor actions. When all possible body systems and environmental conditions are considered in the motor control process, it is easy to understand why there is often a mismatch between the movement plan that is chosen and how it is actually executed. Errors in movements occur and cause problems that the nervous system must solve in order to deliver effective, efficient, accurate plans that meet the task goal. To solve this problem, the CNS creates an internal representation of the body and the surrounding world. This acts as a model that can be adapted and changed in the presence of varying environmental demands. It allows for the ability to predict and estimate the differences between similar situations. This ability is learned by practicing various task configurations in real-life environments. Without experience, accurate movement patterns that consistently meet desired task goals are difficult to achieve.

D. Anticipatory control

Anticipatory control of posture and postural adjustments stabilizes the body by minimizing displacement of the centre of gravity. Anticipatory control involves motor plans that are programmed to act in advance of movement. A comparison between incoming sensory information and knowledge of prior movement successes and failures enables the system to choose the appropriate course of action.

E. Flexibility

A person should have enough flexibility in performance to vary the details of a simple or complex motor plan to meet the challenge presented by any given environmental context. This is a beneficial characteristic of motor control. When considering postural control, for example, a person will typically display a random sway pattern during standing that may ensure continuous, dynamic sensory inputs to multiple sensory systems. The person is constantly adjusting posture and position to meet the demand of standing upright (earth vertical), as well as to seek information from the environment. Rhythmic, oscillating, or stereotypical sway patterns that are unidirectional in nature are not considered flexible and are not as readily adaptable to changes in the environment. Lack of flexibility or randomness in postural sway may actually render the person at greater risk for loss of balance and falls.

Define motor control and then explain what it takes as mentioned above, it has been suggested that motor preparation is reflected in activity of the brain regions associated with motor control and learning. Therefore, the BP has been investigated as an index of activity of those brain regions. Indeed, focusing on the BP, several studies have investigated brain activities associated with retrieval of the generalized motor program. In a target force production task, Masaki and colleagues compared a task repetition condition where participants repeatedly produced the same target force (i.e., 13 N) and an alternation condition where they alternatively produced three different target forces (i.e., 5, 13 and 21 N) in every trial 43).

When participants repeatedly exerted the same target force, they were considered to repeatedly apply the same force parameter to the motor program. Of course, they had to modify the force parameter at each trial using feedback information (knowledge of results), but the modification must have been less effortful than in the alternation condition, in which they had to apply a different force parameter to the motor program in every trial.

Motor control section summary

Motor control theories have been developed and have evolved over many years as our understanding of nervous system structure and function has become more advanced. The control of posture and movement is a complex process that involves many structures and levels within the human body. It requires accurate sensory inputs, coordinated motor outputs, and central integrative processes to produce skilful, goal-directed patterns of movement that achieve desired movement goals. We must integrate and filter multiple sensory inputs from both the internal environment of the body and the external world around us to determine position in space and choose the appropriate motor plan to accomplish a given task.

We combine individual biomechanical and muscle segments of the body into complex movement synergies to deal with the infinite “degrees of freedom” available during the production of voluntary movement. Well learned motor plans are stored and retrieved and modified to allow for flexibility and variety of movement patterns and postures. When the PNS or CNS is damaged and the control of movement is impaired, new, modified, or substitute motor plans can be generated to accomplish goal-directed behaviors, remain adaptable to changing environments, and produce variable movement patterns.

SELF – ASSESSMENT EXERCISE

i. Theories of motor control and learning
ii. Choice of Motor Pattern and The Control of Voluntary Movement

4.0 CONCLUSION

Motor Control Theories include the production of reflexive, automatic, adaptive, and voluntary movements and the performance of efficient, coordinated, goal-directed movement patterns which involve multiple body systems (input, output, and central processing) and multiple levels within the nervous system.

5.0 SUMMARY

Motor control theories provide a framework for interpreting movement and behavior. Motor control is the ability to organize and control functional movement. The field of motor control grew primarily from the specialized study of neurophysiology in an attempt to explain how functional movement is produced and regulated in humans. From a historical perspective, several different theories and models have been proposed. Some models approach motor control from a physiological perspective, and others have a psychological perspective.

6.0 TUTOR – MARKED ASSIGNMENT

Explain Choice of Motor Pattern and The Control of Voluntary Movement under:

1. Coordination
2. Execution
3. Adaptation

7.0 REFERENCES/FURTHER READING

Kimble G.A. (1961). Hilgard and Marquis' Conditioning and Learning. Appleton-Century- Crofts, Inc, New York.

Squire LR, Wixted JT. (2011). The cognitive neuroscience of human memory since H.M. Annu Rev Neurosci 34: 259-288.

Squire L.R. (1987). Memory and Brain. New York: Oxford Univ Press.

Schmidt R.A. (1975). A schema theory of discrete motor skill learning. Psychol Rev 82: 225-260.

Whiting H.A. (1975). Concepts in Skill Learning. Lepus Book, London.

Kantak S.S, Winstein C.J. (2012). Learning-performance distinction and memory processes for motor skills: a focused review and perspective. Behav Brain Res 228: 219-231.

Hallgató E, Győri-Dani D, Pekár J, Janacsek K, Nemeth D. (2012). The differential consolidation of perceptual and motor learning in skill acquisition. Cortex. In press.

Adams J.A. (1971). A closed-loop theory of motor learning. J Mot Behav 3: 111-150.

Keele S.W. (1968). Movement control in skilled motor performance. Psychol Bull 70: 387- 403.

Breedlove S.M, Watson N.V, Rosenzweig M.R. (2010). Biological Psychology: An Introduction to Behavioral, Cognitive, and Clinical Neuroscience. Sinauer Associates Inc., Sunderland, MA, USA.

UNIT 3 MOTOR PROGRAMS AND CENTRAL PATTERN GENERATORS

CONTENTS

1.0 INTRODUCTION

The original reflex model of Sherrington was predicated on the reflex being the basic unit of movement. Reflexes are stereotypical responses to specific sensory stimuli. Sensory information triggers a motor response. There is no response without sensory input. A deep tendon reflex is an example of a monosynaptic reflex. Other reflexes are more complicated and involve more than one level of the nervous system such as an asymmetrical tonic neck reflex. Sherrington thought that voluntary movement was the product of chains of reflexes put together by the brain. Although this explanation of movement being based on reflexes persisted for quite some time, it is incorrect. Movement can occur without a sensory trigger. Reflexive movement tends to be very stereotypical with little or no variability. Motor control theories provide a framework for interpreting movement and behavior. Motor control is the ability to organize and control functional movement. The field of motor control grew primarily from the specialized study of neurophysiology in an attempt to explain how functional movement is produced and regulated in humans. From a historical perspective, several different theories and models have been proposed. Some models approach motor control from a physiological perspective, and others have a psychological perspective. Regardless, it is important to realize that these theories are ever changing and evolving based on contemporary thought and the current research. When the explanations of an existing theory are no longer sufficient to interpret the research data, new theories are developed. Living beings and man, in particular, continuously influence their environment and adapt to varying situations. Adaptation is an active function and critical for survival (and reproduction), and often involves learning, traditionally defined as a relatively permanent change in a behavior potentiality that occurs as a result of reinforced practice1), and the flexible control over and execution of what has been learned. Among the important functions for interacting with the environment are movement and actions. There is strong evidence that the learning and control of such motor skills constitutes a specific domain of competence. Thus, changes in motor behavior (motor learning) usually require practice and often last longer than newly acquired declarative knowledge and memories. For example, once an individual has learned to ride a bicycle, he or she usually maintains this motor skill over many years without further practice.

2.0 OBJECTIVES

After studying this chapter, the reader will be able to:

- Define movement pattern.
- Know the Reflex model theory.
- Identify Control of Voluntary Movement.

3.0 MAIN CONTENT

3.1 Definition of Motor Programs and Pattern

A motor program (MP) is a learned behavioral pattern defined as a neural network that can produce rhythmic output patterns with or without sensory input or central control. MPs are sets of movement commands, or "rules," that define the details of skilled motor actions. An MP defines the specific muscles that are needed, the order of muscle activation, and the force, timing, sequence, and duration of muscle contractions. MPs help control the degrees of freedom of interacting body structures, and the number of ways each individual component acts. A generalized motor program (GMP) defines a pattern of movement, rather than every individual aspect of a movement. GMPs allow for the adjustment, flexibility, and adaptation of movement features according to environmental demands. The existence of MPs and GMPs is a generally accepted concept; however, hard evidence that an MP or a GMP exists has yet to be found. Advancements in brain imaging techniques may substantiate this theory in the future. In contrast to MPs, a central pattern generator (CPG) is a genetically predetermined movement pattern. CPGs exist as neural networks within the CNS and have the capability of producing rhythmic, patterned outputs resembling normal movement. These movements have the capability of occurring without sensory feedback inputs or descending motor inputs. Two characteristic signs of CPGs are that they result in the repetition of movements in a rhythmic manner and that the system returns to its starting condition when the process ceases. Both MPs and CPGs contribute to the development, refinement, production, and recovery of motor control throughout life. Motor - in physical education and studies of the body this refers to movement. ... Motor learning refers to the brain's ability to develop control over the body' muscular skeletal system to produce coordinated and timed movements in response to the demands of the surrounding environment. Motor control is a complex process occurring in the brain in response to practice or experience of a certain skill resulting in changes in the central nervous system. It allows for the production of a new motor skill. ... Motor control requires practice, feedback and knowledge of results. Motor control involves learning a skilled task and then practising with a goal in mind until the skill is executed automatically (Schmidt & Wrisberg 2007). For example, learning to play a song on the piano initially takes a lot of thought and practise before the task is automatic and executed skilfully. In a book entitled Human Performance, the well-known psychologists proposed three stages of learning motor skills: a cognitive phase, an associative phase, and an autonomous phase. During the twentieth century, scholars attempted to explain the mechanisms of motor control. Initially, it was thought that the brain organized movement through reflexes alone or as a hierarchy. Later models were developed that described feedback and programming within the nervous system. A systems model is the most contemporary model of motor control at this time. Motor control is the ability to organize and control functional movement. Each of these models is discussed as follows:

a. The person, the task, and the environment: an ecological model for motor control

Motor control evolves so that people can cope with the environment around them. A person must focus on detecting information in the immediate environment (perception) that is determined to be necessary for performance of the task and achievement of the desired outcome goal. The individual is an active observer and explorer of the environment, which allows the development of multiple ways in which to accomplish (choose and execute) any given task. The individual analyses a particular sensory environment and chooses the most suitable and efficient way to complete the task. The *person* consists of all functional and dysfunctional body structures and functions that exist and interact with one another. The *task* is the goal-directed behavior, challenge, or problem to be solved. The *environment* consists of everything outside of the body that exists, or is perceived to exist, in the external world. All three of these motor control constructs (person, task, environment) are dynamic and variable, and they interact with one another during learning and production of a goal-directed, effective motor plan.

b. Body Structures and Functions That Contribute to The Control of Human Posture and Movement

Keen observation of motor output quality during the performance of functional movement patterns helps the therapist determine activity limitations and begin to hypothesize impairments within sensory, motor, musculoskeletal, cardiopulmonary, and other body systems. The following section presents and defines some of these key factors, including sensory input systems, motor output systems, and structures and functions involved in the integration of information in the CNS.

c. Role of sensory information in motor control

Sensory receptors from somatosensory (exteroceptors and proprioceptors), visual, and vestibular systems and taste, smell, and hearing fire in response to interaction with the external environment and to movement created by the body. Information about these various modalities is transmitted along afferent peripheral nerves to cells in the spinal cord and brain stem of the CNS. All sensory tracts, with the exception of smell, then synapse in respective sensory nuclei of the thalamus, which acts as a filter and relays this information to the appropriate lobe of the cerebral cortex (e.g., somatosensory to parietal lobe, visual to occipital lobe, vestibular, hearing, and taste to temporal lobe). Sensory information is first received and perceived, then associated with other sensory modalities and memory in the association cortex. Once multiple sensory inputs are associated with one another, the person is then able to *perceive* the body, its posture and movement, the environment and its challenges, and the interaction and position of the body with objects within the environment. The person uses this perceptual information to create an internal representation of the body (internal model) and to choose a movement program, driven by motivation and desire, to meet a final outcome goal. Although the sensory input and motor output systems operate differently, they are inseparable in function within the healthy nervous system. Agility, dexterity, and the ability to produce movement plans that are adaptable to environmental demands reflect the accuracy, flexibility, and plasticity of the sensory-motor system.

The CNS uses sensory information in a variety of ways to regulate posture and movement. Before movement is initiated, information about the position of the body in space, body parts in relation to one another, and environmental conditions is obtained from multiple sensory systems. Special senses of vision, vestibular inputs that respond to gravity and movement, and visual-vestibular interactions supply additional information necessary for static and dynamic balance and postural control as well as visual tracking. Auditory information is integrated with other sensory inputs and plays an important role in the timing of motor responses with environmental signals, reaction time, response latency, and comprehension of spoken word. This information is integrated and used in the selection and execution of the movement strategy. During movement performance, the cerebellum and other neural centres use feedback to compare the actual motor behavior with the intended motor plan. If the actual and intended motor behaviors do not match, an error signal is produced and alterations in the motor behavior are triggered. In some instances, the control system anticipates and makes corrective changes before the detection of the error signal. This anticipatory correction is termed *feed-forward control.* Changing one's gait path while walking in a busy shopping mall to avoid a collision is an example of how visual information about the location of people and objects can be used in a feed-forward manner.

Another role of sensory information is to revise the reference of correctness (central representation) of the MP before it is executed again. For example, a young child standing on a balance beam with the feet close together falls off of the beam. An error signal occurs because of the mismatch between the intended motor behavior and the actual motor result. If the child knows that the feet were too close together when the fall occurred, then the child will space the feet farther apart on the next trial. The information about what happened, falling or not falling, is used in planning movement strategies for balancing on any narrow object such as a balance beam, log, or wall in the future. Sensory information is necessary during the acquisition phase of learning a new motor skill and is useful for controlling movements during the execution of the motor plan. However, sensory information is not always necessary when performing well-learned motor behaviors in a stable and familiar context. Rothwell and colleagues studied a man with severe sensory neuropathy in the upper extremity. He could write sentences with his eyes closed and drive a car with a manual transmission without watching the gear shift. He did, however, have difficulty with fine motor tasks such as buttoning his shirt and using a knife and fork to eat when denied visual information. The importance of sensory information must be weighed by the individual, unconsciously filtering and choosing appropriate and accurate sensory inputs to use to meet the movement goal.

Sensory experiences and learning alter sensory representations, or cortical "maps," in the primary somatosensory, visual, and auditory areas of the brain. Training, as well as use and disuse of sensory information, has the potential to drive long-term structural changes in the CNS, including the formation, removal, and remodelling of synapses and dendritic connections in the cortex. This process of cortical plasticity is complex and involves multiple cellular and synaptic mechanisms.

d. Movement preparation

As has been pointed out above, ballistic movements have to be prepared in advance; but preparation for non-ballistic movements is also important. Usually there are two kinds of preparation, time preparation and event preparation; although, in practice, both types usually co-occur. Time preparation relates to the moment in time at which a movement is to be executed. For example, the better a sprinter prepares for the moment of the start signal, the quicker he or she will be able to leave the starting block. In contrast, event preparation refers to the kind of movement to be performed. A goalkeeper preparing for a penalty shot may ready himself/herself to jump to the left or right. Obviously, correct preparation will greatly increase his or her chances to catch the ball. Because there is less neuroscientific work on time preparation (an exception), we will focus on event preparation (for a more in-depth review see Leuthold, Sommer, & Ulrich, 2004).

The paradigm, which has been used most often to study event preparation from a psychophysiological perspective. In this paradigm a prevue provides more or less advance information about the action to be performed in response to a subsequent response signal. A typical experimental result is that the higher the amount of information provided by the prevue, the shorter the reaction time will be to the response signal. For example, Rosenbaum (1980) reported an experiment that required participants to perform a button press with the left or right hand on a button that was located either at a short or long distance from a home key in a direction towards or away from the participant). The required response was fully specified by a response signal. A pre-cut preceding the response signal could provide advance information about the required response. The more information the pre-cut provided, the shorter the reaction time (RT) was to the response signal. Thus, hand information shortened the reaction time, relative to an uninformative pre-cut, and information about hand plus direction shortened the RT even more. Rosenbaum (1980) suggested that the RT benefit occurs because pre-cut information allows parts of the motor program to be assembled in advance of the response signal. This position was contested by Goodman and Kelso (1980) who suggested that the advantage was due to a reduction of stimulus response alternatives, which are obviously fewer when more information is provided, and hence would be functionally localized at the response selection stage.

3.2 Reflex Model Theory

Take it up from reflex theory. The original reflex model of Sherrington was predicated on the reflex being the basic unit of movement. Reflexes are stereotypical responses to specific sensory stimuli. Sensory information triggers a motor response. There is no response without sensory input. A deep tendon reflex is an example of a monosynaptic reflex. Other reflexes are more complicated and involve more than one level of the nervous system such as an asymmetrical tonic neck reflex. Sherrington thought that voluntary movement was the product of chains of reflexes put together by the brain. Although this explanation of movement being based on reflexes persisted for quite some time, it is incorrect. Movement can occur without a sensory trigger. Reflexive movement tends to be very stereotypical with little or no variability. The nervous system does have local circuits at the spinal cord level that coordinate reflexes. Reflexive movement is only one category of movement.

Influence of Neuromuscular Action On Coordinated Movements in Sports

Muscular strength is the base of physical health and fitness and is fundamental for all sports (Khajeh Ne'mat, et al. 2014). Increasing muscular power and neuromuscular coordination is an important physical fitness factor for both body builders and physically active individuals and a minimum level of strength is needed to live a healthy life (Rahimi, et al. 2014). Poor coordination between muscular groups can cause abnormal movements in body parts and this may lead to poor performance and malformation (Hemayat Talab, 2012). Strength trainings improve physical performance by increasing muscle mass, power, strength, speed, kinetic performance, balance and neuromuscular coordination and (Kraeme & Ratamess, 2004). Most researchers believe that muscular power increases through neural or muscular compatibilities or a combination of both. They believe that before beginning a structural change in the muscle, its strength may increase as a result of the change in motor units (Banayi Far, et al. 2011). In other words, strength trainings create new neural channels ending in higher coordination between muscular groups involved in a specific muscular activity (Damirchi, et al. 2007). Several studies have investigated the effects of strength training on the number of Acetylcholine receptors (AchR) and have reported that strength training significantly increases AchR in the muscle (Parnow, et al. 2012). However, in spite of the undeniable effect of strength training on muscle structure and underlying neural mechanisms, recent studies have focused on the effects of strength training on performance. For instance, Kavei, et al. (2014) demonstrated that plyometric and speed trainings have similar mechanism and the plyometric exercise or plyometric exercise combined with speed running induce similar performance improvements. They suggested that these improvements might have been originated from neural adaptations probably caused by further motor units' recruitment and faster neural discharge. Yet, it does not seem that changes in motor reflex play roles in these adaptations. In contrast, Hamre (2013) indicated that fitness factors including reaction time and neuromuscular coordination did not change following a six-week plyometric training. In spite of this contradiction, other studies have reported bilateral effects between strength training and neuromuscular coordination. Enoka, et al. (2012) suggested that the most important factor increasing neuromuscular strength and coordination is the neural system. They found that without neural adaptations strength would not increase. Regarding physiological effects of strength training on neuromuscular system Zarei, et al (2013) showed that that plyometric training induces great changes in neuromuscular coordination and compatibility which leads to increased muscles power, faster reaction and improved sports performance. Accordingly, studies conducted by McCarthy, et al. (2012), Tine-Alkjear, et al. (2013) and Menz, et al. (2013) approved of the relationship between two variables.

However, the nature and manner of neuromuscular coordination and compatibility induced by strength programs is not very well understood. Moreover, results from various studies are contradictory (Wulkow, et al. 2011). Studies have reported that developments in neural system occur in primary stages of training and structural formation of muscles (hypertrophy) follows this stage. Furthermore, lack of enough understanding about the nature of neural conductivity, whether it is hereditary or adaptability, poses a question that neural compatibilities do not occur or are not significant in trained athletes (Bompa, 2008). Considering the contradictory results and increasing attention to strength trainings to improve physical fitness, proposing novel solutions for succeeding in international events of different sports including emerging individual and team sports seems to be crucial. Therefore, this question arises that whether strength training increase neuromuscular coordination and compatibility in pool players and improves target tracking and shot control. Thus, the present study investigates the effects of strength training on neuromuscular coordination in pool players.

The neuromuscular junction (NMJ) is a synapse site from peripheral nervous system that allows communication between α-moto neuron and skeletal muscle fibres. NMJ architecture is formed by pre- and post-synaptic compartments. Each compartment consists of several components, such as peripheral axon, myelin sheath, Schwann cells, acetylcholine (ACh) vesicles and receptors (AChR), acetylcholinesterase enzyme, and muscle basal lamina.

One classical feature of this morphological structure is the great plasticity that it suffers across age. Experimental data demonstrated greater NMJ density in juvenile than adult rats. From young to adult age, skeletal muscle fibre goes from a multi-innervated condition to a unique NMJ/muscle fibre state. As time passes by, nervous system begins to suffer a slow and continued reduction of its functions. At late ages, NMJ begins to undergo a process of functional denervation, leading to compensatory functional hypertrophy frame. This mechanism is an attempt to prevent the muscle fibres are permanently enervated and undergo apoptosis. This process may lead skeletal muscle to sarcopenia process.

Many strategies are studied in order to stop and/or reverse the sarcopenia process and muscle strength decrease resulted from the advanced biological age. Undoubtedly, one of the most researched and used strategy is physical exercise. Physical exercise can be considered as any physical activity previously scheduled. The relationship between physical exercise and NMJ is studied since the middle of last century. Exercise can promote positive changes in NMJ and thereby promote functional capacity improvement of young and old human and animals. Therefore, this type of intervention is extremely important to maintain the physical functional condition over time. Despite some information on the effect of exercise training on the structure of the NMJ, many studies analysed different lab techniques, skeletal muscles, exercise types and training protocols. These methodological differences might lead us to conflicting, confusing and/or divergent results.

Many molecules have been proposed to participate at NMJ adaptation to exercise. Recently, Nishimune and colleagues reviewed literature-showing probability of molecules such as *insulin like growth factors* (IGFs), *Bassoon* protein, neurotrophin 4 (NT-4) and other to induce NMJ physiological and morphological adaptation to training. However, more data are needed and further mechanisms might be involved in this scene.

Currently, the clinical literature uses systematic reviews and meta-analysis to identify possible studies methodological differences, quality of the surveyed studies on a given topic and the most suitable intervention for a specific treatment. Therefore, this study aimed to carry out a systematic review on the effects of exercise on NMJ compartments of young, adult and aged animals. Motor competence reflects the degree of proficient performance in various motor skills and is essential for developing an active and healthy lifestyle. If a child has motor problems and is left untreated, he is likely to transfer them into adulthood. Moreover, low motor competence can lead to risks for a mixture of behavioral, emotional, and social difficulties. Additionally, it also significantly impacts the willingness of participation in physical activity and overall performance in different sports.

Volleyball is one of the most intense anaerobic sports that include a combination of explosive movements with short recovery periods. In volleyball, the physical performance plays an essential role, since the actions in this sport include a variety of changes of direction in sagittal and frontal planes, frequent sprints, and different types of jumps. Explosive strength represents the ability of the neuromuscular system to manifest strain as quickly as possible and is a crucial fundamental aspect of successful volleyball performance. Besides the importance of physical performance, volleyball can also be considered a skill-based and complex game, which requires well-developed motor coordination levels. The importance of effective motor behavior optimization and decisionmaking in different motor games was established recently. Moreover, Pic et al. found that girls and boys show differences in the effectiveness of motor behavior and respond differently when they act within a complex interactive structure. Therefore, well-developed programs and methodologies are essential and can significantly contribute to motor skill learning and improving movement competence.

Therefore, different kinds of training models have been tested to improve the performance of volleyball players. However, there is a high degree of inter-individual variation in the development of movement competence during early and middle childhood. Accordingly, exercise and health care professionals agree that we should put the focus on appropriate training models for the youth. The evidence says that a supervised strength training program is effective and safe for children and that they can successfully improve their overall health and strength by participating in such a program. The neuromuscular training (NMT) program was identified as a new innovative approach for school children. It aims to include general and specific physical activities to enhance health (e.g., endurance and strength) and skill-related (e.g., balance and agility) physical fitness components with a combination of resistance, balance, dynamic stability, plyometric, core strength, and agility exercises. Faigenbaum et al. reported that the NMT program showed results in the enhancement of children’s fundamental movement skills and fitness. Faigenbaum et al. demonstrated significant improvements after eight weeks of 15 min NMT before-school physical education, in curl-ups, push-ups, 0.5-mile run, and single-leg hop performance, compared to the control group. While the mentioned research adds valuable meaning to NMT, there is still a lack of NMT research on young volleyball players. In adolescent female volleyball players, the NMT program resulted in the improvement of their neuromuscular control and decrease of anterior cruciate ligament (ACL) injury risk by improving dynamic knee stability. Another study showed that regular participation in NMT enhanced countermovement jumping performance in young volleyball players. Sugimoto et al. demonstrated on a sample of 21 high school women volleyball players that the high compliance to NMT significantly elevated the hip abductors isokinetic strength. However, multiple questions remain regarding the efficacy and utility of NMT as a tool to enhance motor competence and physical performance in young athletes, especially in volleyball. Besides that, there is not a sufficient amount of research on this field on the female population. Females may especially benefit from multicomponent NMT since they usually display decreased baseline levels of power and strength in comparison with the male population.

3.3 Control of Voluntary Movement

Table below provided by researchgate.net shows the body system processes involved in motor control, their actions, and the body structures included. The following section explains these processes in more detail.

Components of Motor Control: Body System Processes Involved in Motor Control, Their Actions, and The Body Structures Included

PROCESS	ACTION	BODY STRUCTURES INVOLVED
Sensation	Sensory information, feedback from exteroceptors and proprioceptors	Peripheral afferent neurons, brain stem, cerebellum, thalamus, sensory receiving areas in the parietal, occipital, and temporal lobes
Perception	Combining, comparing, and filtering sensory inputs	Brain stem, thalamus, sensory association areas in the parietal, occipital, visual, and temporal lobes
Choice of movement plan	Use of the perceptual map to access the appropriate motor plan	Association areas, frontal lobe, basal ganglia
Coordination	Determining the details of the plan including force, timing, tone, direction, and extent of the movement of postural and limb synergies and actions	Frontal lobe, basal ganglia, cerebellum, thalamus

PROCESS	ACTION	BODY STRUCTURES INVOLVED
Execution	Execution of the motor plan	Corticospinal and corticobulbar tract systems, brain stem motor nuclei, and alpha and gamma motor neurons
Adaptation	Compare movement with the motor plan and adjust the plan during performance	Spinal neural networks, cerebellum

Role of the cerebellum

The primary roles of the cerebellum are to maintain posture and balance during static and dynamic tasks and to coordinate movements before execution and during performance. The cerebellum processes multiple neural signals from (1) motor areas of the cerebral cortex for motor planning, (2) sensory tract systems (dorsal spinal cerebellar tract, ventral spinal cerebellar tract) from muscle and joint receptors for proprioceptive and kinaesthetic sense information resulting from movement performance, and (3) vestibular system information for the regulation of upright control and balance at rest and during movements. It compares motor plan signals driven by the cortex with what is received from muscles and joints in the periphery and makes necessary adjustments and adaptations to achieve the intended coordinated movement sequence. Movements that are frequently repeated "instructions" are stored in the cerebellum as procedural memory traces. This increases the efficiency of its role in coordinating movement. The cerebellum also plays a role in function of the reticular activating system (RAS). The RAS network exists in the brain stem tegmentum and consists of a network of nerve cells that maintain consciousness in humans and help people focus attention and block out distractions that may affect motor performance. Damage to the cerebellum, its tract systems, or its structure creates problems of movement coordination, not execution or choice of which program to run. The cerebellum also plays a role in language, attention, and mental imagery functions that are not considered to take place in motor areas of the cerebral cortex.

The Cerebellum Plays Four Important Roles in Motor Control

1. ***Feed-forward processing***: The cerebellum receives neural signals, processes them in a sequential order, and sends information out, providing a rapid response to any incoming information. It is not designed to act like the cerebral cortex and does not have the capability of generating self-sustaining neural patterns.
2. ***Divergence and convergence***: The cerebellum receives a great number of inputs from multiple body structures, processes this information extensively through a structured internal network, and sends the results out through a limited number of output cells.
3. ***Modularity*****:** The cerebellum is functionally divided into independent modules—hundreds to thousands—all with different inputs and outputs. Each module appears to function independently, although they each share neurons with the inferior olives, Purkinje cells, mossy and parallel fibres, and deep cerebellar nuclei.
4. ***Plasticity*****:** Synapses within the cerebellar system (between parallel fibres and Purkinje cells, and synapses between mossy fibres and deep nuclear cells) are susceptible to modification of their output strength. The influence of input on nuclear cells is adjustable, which gives great flexibility to adjust and fine-tune the relationship between cerebellar inputs and outputs.

Role of the basal ganglia

The basal ganglia are a collection of nuclei located in the forebrain and midbrain and consisting of the globus pallidus, putamen, caudate nucleus, substantia nigra, and subthalamic nuclei. It has primary functions in motor control and motor learning. It plays a role in deciding which motor plan or behavior to execute at any given time. It has connections to the limbic system and is therefore believed to be involved in "reward learning." It plays a key role in eye movements through midbrain connections with the superior colliculus and helps to regulate postural tone as a basis for the control of body positions, preparedness, and central set.

Information processing

The processing of information through the sensory input, motor output, and central integrative structures occurs by various methods to produce movement behaviors. These methods allow us to deal with the temporal and spatial components necessary for coordinated motor output and allow us to anticipate so that a response pattern may be prepared in advance. *Serial processing* is a specific, sequential order of processing of information through various centres. Information proceeds lockstep through each centre. *Parallel processing* is processing of information that can be used for more than one activity by more than one centre simultaneously or nearly simultaneously. A third and more flexible type of processing of information. This type of processing combines the best attributes of serial and parallel processing. When the situation demands serial processing, this type of activity occurs. At other times parallel processing is the mode of choice. For optimal processing of intrinsic and extrinsic sensory information by various regions of the brain, a combination of both serial and parallel processing is the most efficient mode. The type of processing depends on the constraints of the situation. For example, maintaining balance after an unexpected external perturbation requires rapid processing, whereas learning to voluntarily shift the centre of gravity to the limits of stability requires a different combination of processing modes.

Methods of information processing

In summary, information processing reinforces and refines motor patterns. It allows the organism to initiate compensatory strategies if an ineffective motor pattern is selected or if an unexpected perturbation occurs. And, most important, information processing facilitates motor learning.

Movement patterns arising from self-organizing subsystems

Coordinated movement patterns are developed and refined via dynamic interaction among body systems and subsystems in response to internal and external constraints. Movement patterns used to accomplish a goal are contextually appropriate and arise as an emergent property of subsystem interaction. Several principles relate to self-organizing systems: reciprocity, distributed function, consensus, and emergent properties.

Reciprocity implies information flow between two or more neural networks. These networks can represent specific brain centres, for example, the cerebellum and basal ganglia. Alternatively, the neural networks can be interacting neuronal clusters located within a single centre, for example, the basal ganglia. One model to demonstrate reciprocity is the basal ganglia regulation of motor behavior through direct and indirect pathways to cortical areas. The more direct pathway from the putamen to the globus pallidus internal segment provides net inhibitory effects. The more indirect pathway from the putamen through the globus pallidus external segment and sub thalamic nucleus provides a net excitatory effect on the globus pallidus internal segment. Alteration of the balance between these pathways is postulated to produce motor dysfunction. An abnormally decreased outflow from the basal ganglia is postulated to produce involuntary motor patterns, which produce excessive motion such as chorea, hemiballism, or nonintentional tremor. Alternatively, an abnormally increased outflow from the basal ganglia is postulated to produce a paucity of motions, as seen in the rigidity observed in individuals with Parkinson disease.

Systems model of motor control

Distributed function presupposes that a single centre or neural network has more than one function. The concept also implies that several centres share the same function. For example, a centre may serve as the coordinating unit of an activity in one task and may serve as a pattern generator or oscillator to maintain the activity in another task. An advantage of distributing function among groups of neurons or centres is to provide centres with overlapping or redundant functions. Neuroscientists believe such redundancy is a safety feature. If a neuronal lesion occurs, other centres can assume critical functional roles, thereby producing recovery from CNS dysfunction.

Consensus implies that motor behavior occurs when a majority of brain centres or regions reach a critical threshold to produce activation. Also, through consensus extraneous information or information that does require immediate attention is filtered. If, however, a novel stimulus enters the system, it carries more weight and receives immediate attention. A novel stimulus may be new to the system, may reflect a potentially harmful situation, or may result from the conflict of multiple inputs.

Emergent properties may be understood by the adage “the whole is greater than the sum of its parts.” This concept implies that brain *centres,* not a single brain centre, work together to produce movement. An example of the emergent properties concept is continuous repetitive activity (oscillation). a hierarchy is represented by three neurons arranged in tandem. The last neuron ends on a responder. If a single stimulus activates this network, a single response occurs. What is the response if the neurons are arranged so that the third neuron sends a collateral branch to the first neuron in addition to the ending on the responder In this case a single stimulus activates neuron No. 1, which in turn activates neurons No. 2 and No. 3, causing a response as well as reactivating neuron No. 1. This neuronal arrangement produces a series of responses rather than a single response. This process is also termed *endogenous activity.*

Another example of an emergent property is the production of motor behavior. Rather than having every MP stored in the brain, an abstract representation of the intended goal is stored. At the time of motor performance, various brain centres use the present sensory information, combined with past memory of the task, to develop the appropriate motor strategy. This concept negates a hardwired MP concept. If MPs were hardwired and if an MP existed for every movement ever performed, the brain would need a huge storage capacity and would lack the adaptability necessary for complex function.

Controlling the degrees of freedom

Combinations of muscle and joint action permit a large number of degrees of freedom that contribute to movement. A system with a large number of degrees of freedom is called a *high-dimensional system.* For a contextually appropriate movement to occur, the number of degrees of freedom needs to be constrained. Bernstein suggested that the number of degrees of freedom could be reduced by muscles working in synergies, that is, coupling muscles and joints of a limb to produce functional patterns of movement. The functional unit of motor behavior is then a *synergy.* Synergies help to reduce the degrees of freedom, transforming a high-dimensional system into a low-dimensional system. For example, a step is considered to be a functional synergy pattern for the lower extremity. Linking together stepping synergies with the functional synergies of other limbs creates locomotion (inter limb coordination).

Functional synergy implies that muscles are activated in an appropriate sequence and with appropriate force, timing, and directional components. These components can be represented as fixed or "relative" ratios, and the control comes from input given to the cerebellum from higher centres in the brain and the peripheral or spinal system and from prior learning. The relative parameters are also termed *control parameters.* Scaling control parameters leads to a change in motor behavior to accomplish the task. For example, writing your name on the blackboard exemplifies scaling force, timing, and amplitude. Scaling is the proportional increase or decrease of the parameter to produce the intended motor activity.

Coordinated movement is defined as an orderly sequence of muscle activity in a single functional synergy or the orderly sequence of functional synergies with appropriate scaling of activation parameters necessary to produce the intended motor behavior. Uncoordinated movement can occur at the level of the scaling of control parameters in one functional synergy or inappropriate coupling of functional synergies. The control parameter of duration will be used to illustrate scaling. If muscle A is active for 10% of the duration of the motor activity and muscle B is active 50% of the time, the fixed ratio of A/B is 1:5. If the movement is performed slowly, the relative time for the entire movement increases. Fixed ratios also increase proportionally. Writing your name on a blackboard very small or very large yields the same results—your name. Timing of muscle on/off activation for antagonistic muscles such as biceps and triceps, or hamstrings and quadriceps, needs to be accurate for coordination and control of movement patterns. If one muscle group demonstrates a delayed onset or maintains a longer duration of activity, overlapping with triceps "on" time, the movement will appear uncoordinated. Patients with neurological dysfunction often demonstrate alterations in the timing of muscle activity within functional synergies and in coupling functional synergies to produce movement. These functional movement synergies are not hardwired but represent emergent properties. They are flexible and adaptable to meet the challenges of the task and the environmental constraints.

Finite number of movement strategies

The concept of *emergent properties* could conceivably imply an unlimited number of movement strategies available to perform a particular task. However, limiting the degrees of freedom decreases the number of strategies available for selection. In addition, constraints imposed by the internal environment (e.g., musculoskeletal system, cardiovascular system, metabolic activity, cognition) and external environment (e.g., support surface, obstacles, lighting) limit the number of movement strategies. Horak and Nashner observed that a finite number of balance strategies were used by individuals in response to externally applied linear perturbations on a force plate system. With use of a life span approach, VanSant identified a limited number of movement patterns for the upper limb, head-trunk, and lower limb for the task of rising from supine to standing.

The combination of these strategies produces the necessary variability in motor behavior. Although an individual has a preferred or modal profile, the healthy person with an intact neuromuscular system can combine strategies in various body regions to produce different movement patterns that also accomplish the task. Persons with neurological deficits may be unable to produce a successful, efficient movement pattern because of their inability to combine strategies or adapt a strategy for a given environmental change (e.g., differing chair height for sit-to-stand transitions).

Variability of movements implies normalcy

A key to the assessment and treatment of individuals with neurological dysfunction lies in variability of movement and in the notion that variability is a sign of normalcy, and stereotypical behavior is a sign of dysfunction.

Age, activity level, the environment, constraints of a goal, and neuropathological conditions affect the selection of patterns available for use during movement tasks. When change occurs in one or more of the neural subsystems, a new movement pattern emerges. The element that causes change is called a *control parameter*. For example, an increase in the speed of walking occurs until a critical speed and degree of hip extension are reached, thereby switching the movement pattern to a run. When the speed of the run is decreased, there is a shift back to the preferred movement pattern of walking. A control parameter shifts the individual into a different pattern of motor behavior.

This concept underlies theories of development and learning. Development and learning can be viewed as moving the system from a stable state to a more unstable state. When the control variable is removed, the system moves back to the early, more stable state. As the control variable continues to push the system, the individual spends more time in the new state and less time in the earlier state until the individual spends most of the time in the new state. When this occurs, the new state becomes the preferred state. Moving or shifting to the new, preferred state does not obviate the ability of the individual to use the earlier state of motor behavior. Therefore, new movement patterns take place when critical changes occur in the system because of a control parameter but do not eliminate older, less-preferred patterns of movement.

Motivation to accomplish a task in spite of functional limitations and neuropathological conditions can also shift the individual's CNS to select different patterns of motor behavior. The musculoskeletal system, by nature of the architecture of the joints and muscle attachments, can be a constraint on the movement pattern. An individual with a functional contracture may be limited in the ability to bend a joint only into a desired range, thereby decreasing the movement repertoire available to the individual. Such a constraint produces adaptive motor behavior. Dorsiflexion of the foot needs to meet a critical degree of toe clearance during gait. If there is a range of motion limitation in dorsiflexion, then biomechanical constraints imposed on the nervous system will produce adaptive motor behaviors (e.g., toe clearance during gait). Changes in motor patterns during the task of rising from supine to standing are observed when healthy individuals wear an orthosis to limit dorsiflexion. The inability to easily open and close the hand with rotation may lead to adaptations that require the shoulder musculature to place the hand in a more functional position. This adaptation uses axial and trunk muscles and will limit the use of that limb in both fine and gross motor performance.

Preferred, no obligatory movement patterns that are stable yet flexible enough to meet ever-changing environmental conditions are considered *attractor states.* Individuals can choose from a variety of movement patterns to accomplish a given task. For example, older adults may choose from a variety of fall-prevention movement patterns when faced with the risk of falling. The choice of motor plan may be negatively influenced by age-related declines in the sensory input systems or a fear of falling. For example, when performing the Multi-Directional Reach Test, an older adult may choose to reach forward, backward (lean), or laterally without shifting the centre of gravity toward the limits of stability. This person has the capability of performing a different reaching pattern if asked, but prefers a more stable pattern.

Obligatory and stereotypical movement patterns suggest that the individual does not have the capability of adapting to new situations or cannot use different movement patterns to accomplish a given task. This inability may be a result of internal constraints that are functional or pathophysiological. The patient who has had a stroke has CNS constraints that limit the number of different movement patterns that can emerge from the self-organizing system. With recovery, the patient may be able to select and use additional movement strategies. Cognition and the capability to learn may also limit the number of movement patterns available to the individual and the ability of the person to select and use new or different movement patterns.

Obligatory and stereotypical movement patterns also arise from external constraints imposed on the organism. Consider the external constraints placed on a concert violin player. These external constraints include, for example, the length of the bow and the position of the violin. Repetitive movement patterns leading to cumulative trauma disorder in healthy individuals can lead to muscular and neurological changes. Over time, changes in dystonic posturing and changes in the somatosensory cortex have been observed. Although one hypothesis considers that the focal dystonia results from sensory integrative problems, the observable result is a stereotypical motor problem.

To review, the nervous system responds to a variety of internal and external constraints to develop and execute motor behavior that is efficient to accomplish a specific task. Efficiency can be examined in terms of metabolic cost to the individual, type of movement pattern used, preferred or habitual movement (habit) used by the individual, and time to complete the task. The term *attractor state* is used in dynamical systems theory to describe the preferred pattern or habitual movement.
Individuals with neurological deficits may have limited repertoires of movement strategies available. Patients experiment with various motor patterns in order to learn the most efficient, energy-conscious motor strategy to accomplish the task. Therapists can plan interventions that help to facilitate refinement of the task to match the patient's capability, allowing the task to be completed using a variety of movement strategies rather than limited stereotypical strategies, leading to an increase in function.

SELF – ASSESSMENT EXERCISE

i. Explain Neural basis of motor learning.
ii. Define motor control.
iii. Give account of motor learning theories.

4.0 CONCLUSION

There is no response without sensory input. A deep tendon reflex is an example of a monosynaptic reflex. Other reflexes are more complicated and involve more than one level of the nervous system such as an asymmetrical tonic neck reflex. Sherrington thought that voluntary movement was the product of chains of reflexes put together by the brain. Although this explanation of movement being based on reflexes persisted for quite some time, it is incorrect.

5.0 SUMMARY

The concept underlies theories of development and learning. Development and learning can be viewed as moving the system from a stable state to a more unstable state. When the control variable is removed, the system moves back to the early, more stable state. As the control variable continues to push the system, the individual spends more time in the new state and less time in the earlier state until the individual spends most of the time in the new state. When this occurs, the new state becomes the preferred state. Moving or shifting to the new, preferred state does not obviate the ability of the individual to use the earlier state of motor behaviour movement.

6.0 TUTOR – MARKED ASSIGNMENT

1. Define movement pattern.
2 Know the Reflex model theory.
3. Identify Control of Voluntary Movement.

7.0 REFERENCES/FURTHER READING

Kimble G.A. (1961). Hilgard and Marquis' Conditioning and Learning. Appleton-Century-Crofts, Inc, New York.

Squire LR, Wixted JT. (2011). The cognitive neuroscience of human memory since H.M. Annu Rev Neurosci 34: 259-288.

Squire L.R. (1987). Memory and Brain. New York: Oxford Univ Press.

Schmidt R.A. (1975). A schema theory of discrete motor skill learning. Psychol Rev 82: 225-260.

Whiting H.A. (1975). Concepts in Skill Learning. Lepus Book, London.

Kantak S.S, Winstein C.J. (2012). Learning-performance distinction and memory processes for motor skills: a focused review and perspective. Behav Brain Res 228: 219-231. Hallgató E, Győri-Dani D, Pekár J, Janacsek K, Nemeth D. (2012). The differential consolidation of perceptual and motor learning in skill acquisition. Cortex. In press.

Adams J.A. (1971). A closed-loop theory of motor learning. J Mot Behav 3: 111-150.

Keele S.W. (1968). Movement control in skilled motor performance. Psychol Bull 70: 387-403.

Breedlove S.M, Watson N.V, Rosenzweig M.R. (2010). Biological Psychology: An Introduction to Behavioral, Cognitive, and Clinical Neuroscience. Sinauer Associates Inc., Sunderland, MA, USA.

MODULE 4

UNIT 1 KINAESTHESIA

CONTENTS

1.0 INTRODUCTION

People rely on their senses to successfully interact with the surrounding environment. During movement, specialized senses enable perception of self or extrinsically induced movement of our bodies. Three different but basic senses have been recognized, to be of importance for regulation of human movement. These are vision, vestibular and kinesthesia or proprioception (Guerraz & Bronstein, 2008; Mergner, 2007; Soechting & Flanders, 2008). This review is going to focus on kinaesthetic sense but it should be kept in mind that other senses are functionally and neurologically linked or interwoven with kinaesthesia. In sports, the development of the kinaesthetic sense itself is almost never the primary focus of training interventions. Its improvement rather happens in parallel to other functional and structural changes which are the primary aim of a certain type of training. Kinaesthetic sense is thought to be developed by some degree using sensory-motor training (Vuillerme, Teasdale, & Nougier, 2001). In the last decade, kinaesthesia has been correlated to sports injury prevention and rehabilitation, and is proposed to be an important factor in re-establishing proper motor control after injury (Riemann & Lephart, 2002). But kinaesthesia is not an isolated sense or ability, rather an integral part of the movement controlling system. As its sub-modality, kinaesthesia is responsible for perceiving specific characteristics of our own movement, and for being able to correct it accordingly to the goals or demands of the movement and the task performed (Proske, 2006).

Kinesthesia takes five different perspectives on kinesthesia, beginning with its evolution across animate life and its biological distinction from, and relationship to proprioception. It proceeds to document the historical derivation of “the muscle sense,” showing in the process how analytic philosophers bypass the import of kinesthesia by way of “inaction,” for example, and by redefinitions of “tactical deception.” The article then gives prominence to a further occlusion of kinaesthesia and its subduction by proprioception, these practices being those of well-known phenomenologists, practices that exemplify an adultism perspective supported in large part by the writings of Merleau-Ponty. Following this extended critical review, the article shows how Husserl’s phenomenology enlightens us about kinaesthesia and in doing so offers us substantive clues to the phenomenology of learning as it takes place in the development and acquisition of skilful movement.

2.0 OBJECTIVES

At the end of the studies the students will learn the following:

- Proprioception of the muscle sense and kinaesthesia
- Evolutionary considerations.
- An adultism perspective exemplified.
- Husserl’s insights and phenomenological methodology.
- Empirical validation of Husserl’s insights and its import.

3.0 MAIN CONTENT

3.1 Meaning of Kinaesthesia

Kinaesthesia is the awareness of the position and movement of the parts of the body using sensory organs, which are known as proprioceptors, in joints and muscles. Kinaesthesia is a key component in muscle memory and hand-eye coordination. The discovery of kinaesthesia served as a precursor to the study of proprioception. While the terms proprioception and kinaesthesia are often used interchangeably, they actually have many different components. Often the kinaesthetic sense is differentiated from proprioception by excluding the sense of equilibrium or balance from kinaesthesia. An inner ear infection, for example, might degrade the sense of balance. This would degrade the proprioceptive sense, but not the kinaesthetic sense. The affected individual would be able to walk, but only by using the sense of sight to maintain balance; the person would be unable to walk with eyes closed. Another difference in proprioception and kinaesthesia is that kinaesthesia focuses on the body’s motion or movements, while proprioception focuses more on the body's awareness of its movements and behaviors. This has led to the notion that kinaesthesia is more behavioral, and proprioception is more cognitive.

Reflexes combine the spinal sensory and motor components with a sensory input that directly generates a motor response. The reflexes that are tested in the neurological exam are classified into two groups. A deep tendon reflex is commonly known as a stretch reflex and is elicited by a strong tap to a tendon, such as in the knee-jerk reflex. A superficial reflex is elicited through gentle stimulation of the skin and causes contraction of the associated muscles.

Knee-jerk reflex, also called patellar reflex, sudden kicking movement of the lower leg in response to a sharp tap on the patellar tendon, which lies just below the kneecap (Fig.3.1.1). One of the several positions that a subject may take for the test is to sit with knees bent and with one leg crossed over the other so that the upper foot hangs clear of the floor. The sharp tap on the tendon slightly stretches the quadriceps, the complex of muscles at the front of the upper leg. In reaction, these muscles contract and the contraction tends to straighten the leg in a kicking motion. Exaggeration or absence of the reaction suggests that there may be damage to the central nervous system. The knee jerk can also be helpful in recognizing thyroid disease. Kinaesthesia is the ability to sense motion of a joint or limb. It is primarily influenced by muscle spindles and secondarily influenced by skin receptors and joint receptors. In research, as well as in sports and rehabilitation literature, different terms such as proprioception, sensory-motor function, balance and kinesthesia are often interchangeably used. Usually the same subject of interest is discussed but from various perspectives. Proprioception has been often falsely used to describe function of the motor controlling mechanisms during movement, especially awareness of movement, reaction to perturbation and prevention of injury. As argued by Riemann and Lephart (2002) and Lephart, Reimann, and Fu (2000) proprioception has been well defined by sir Sheringhton in the beginning of the 20th century. Sheringhton`s description of proprioception was not as broad as the today's understanding is. He described it as the sensory information originating from proprioceptors, being sensory organs sensitive to changes that take place in the organism itself (Lephart et al., 2000). Today proprioception is often discussed in the context of joint stability. Functional joint stability is one of the prime sports injury preventive factors. Sensing unpredicted joint rotations is the basis for proper motor reactions. The concept of active joint stability is focused on sensory-motor function. kinesthesia as a sense of position and movement of the limbs and the trunk. For an overview of the discussion on the different definitions of kinesthesia, the reader is advised to reed previously published papers (Lephart et al., 2000; Proske & Gandevia, 2009). Kinanesthesia is an important part of human movement control and provides us with better understanding of specific movement system adaptations to fatigue, training and injury. Additionally, decreased

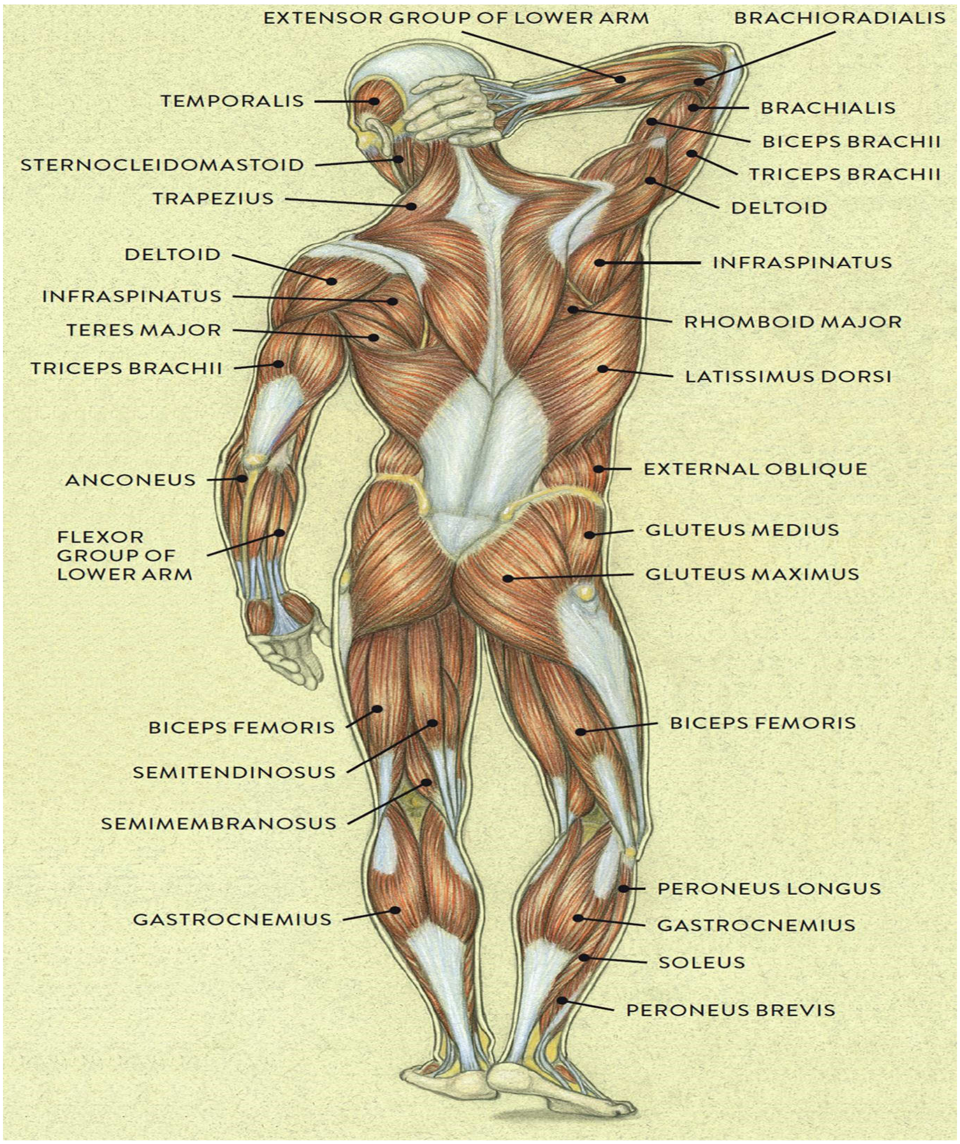
3.2 Kinaesthesia as a part of a more general motor controlling mechanism

Kinesthesia can be an injury predisposing factor, which stresses the necessity for its assessment in sports injury prevention programs. First, terminology and functional concept of kinesthesia is presented in relation to other related concepts like proprioception and sensory-motor function. For better understanding, basic underlying neurological backgrounds are discussed in chapter two, encompassing peripheral sensory fields as well as the basics of the central processing. Additionally, factors affecting kinesthesia and its adaptations to training are presented. Functional aspects are discussed, supporting the role of assessment of kinaesthesia in sports and rehabilitation. In the third chapter, a proposal for measuring methods classification is given. The kinaesthetic sense is from functional and neurophysiological perspective a part of a motor controlling system and represents its sub-modality. This information is important for the movement controlling system which must be supported with the information on the movement in progress. From this perspective, information of the onset of the movement, velocity, acceleration, direction of movement, and position of an individual limb or joint in time are of importance to enable detection of the movement progress and deviations from the expected trajectory. These deviations can be caused by extrinsic or in- transit perturbations. For example, perturbations like unexpected change in load that is being carried or other unexpected environmental changes. Perturbations, like sudden increase in radial forces during skiing on divers snow or unforeseen change in ground consistence during running demand adaptive activity of the locomotor system. Based on this feedback better comparison between expected and actual movement can be better met. Researchgate.net.2001.

3.2.1 Muscle-tendon system

Muscle spindles and tendon organs are types of encapsulated proprioceptive sense organs found in skeletal muscle, and important for motor control. Tendon organs typically have single sensory endings of group Ib nerve fibers and are located at the myo-tendinous junction. The golgi tendon organ is a proprioceptor, sense organ that receives information from the tendon, that senses TENSION. When you lift weights, the golgi tendon organ is the sense organ that tells you how much tension the muscle is exerting.

An important role to perception of human movement has been ascribed to the proprioceptors located in the muscles. The tendon organ is a stretch receptor that signals the force developed by the muscle. The sensory endings of the afferent are entwined amongst the muscular tendinous strands of 10-20 extradural muscle fibers. Two main proprioceptors, thought to significantly contribute to kinesthetic, are the muscle spindle and the Golgi tendon organ as indicated in the figure below figure as shown with pictures.



Muscle spindle is a fusiform-shaped organ, with its polar ends attached to muscle fibers. It is a specialized organ that consists of encapsulated muscle fibers, called intrafusal muscle fibers (Windhorst, 2007). From functional perspective there are different types of muscle spindles, but this diversity surpasses the scope of this text. In the center of the muscle spindles, lie small nerve endings, sensitive to stretch of the capsule, or intrafusal muscle fibers.

When they are stimulated, afferent impulses are conveyed to the spinal cord. It differs from other sensors by its own motor innervation of intrafusal muscle fibers via the γ-motor neuron. As the nature of the muscle spindle structure suggests, it is sensitive to tension induced by muscle stretch. It is thought that it contributes to the sense of muscle length, velocity of its contraction and the rate of muscle stretch. Some researchers argue that sensory information arriving from the muscle spindle is far too complex to contribute to the sense of position (McCloskey, 1978; Proske, 2005). Their arguments are based on specific characteristics of the muscle spindle innervations and its influence on the afferent output. Intrafusal muscle fiber can contract and stimulate intrafusal nervous structures, causing the muscle spindle afferent discharge, even if the muscle is not stretched.

Sensory signals derived may not be exclusively a consequence of change in the muscle length. This discrepancy between firing after muscle stretching resulting from outer forces or stretching due to γ activity is enabled by a complex coordination of α and γ motor neurons, called α γ captivation.

This debate remains open for future research. Nevertheless, the motor system controls the excitability of muscle spindles and consequently influences sensory information and consequently muscle contraction. But the muscle spindle system can be influenced by other factors that have an important effect on the way sensory information is discharged. The motor neuron is governed by higher nerve centres. There are also evidences that suggest that other proprioceptors from joint ligaments, capsule, menisci and skin can influence the excitability of muscle spindle with direct influence on the γ-motor neuron (Johansson et al., 1991). The exact nature of these connections remains unknown, but research has shown that peripheral sensory information can profoundly affect the muscle spindles afferent firing (Johansson, Pedersen, & Bergenheim, 2000; Johansson et al., 1991). This suggests that the position of the joint and stress put on the skin can influence kinesthetic sense fibers of tendons.

3.2.2 Joint Structures and their Sensory Role

Joints can be thought of as hinges, where an actual movement of a body segment takes place. Different soft joint tissues function as joint movement restraints and act as stabilizers. During movement this soft tissue is mechanically stressed, causing stimulation of imbedded proprioceptors. It was not until the mid-20th century that the first proofs were presented that joint ligaments have a neurological function besides their already recognized mechanical stabilizing function (Solomonow, 2006).

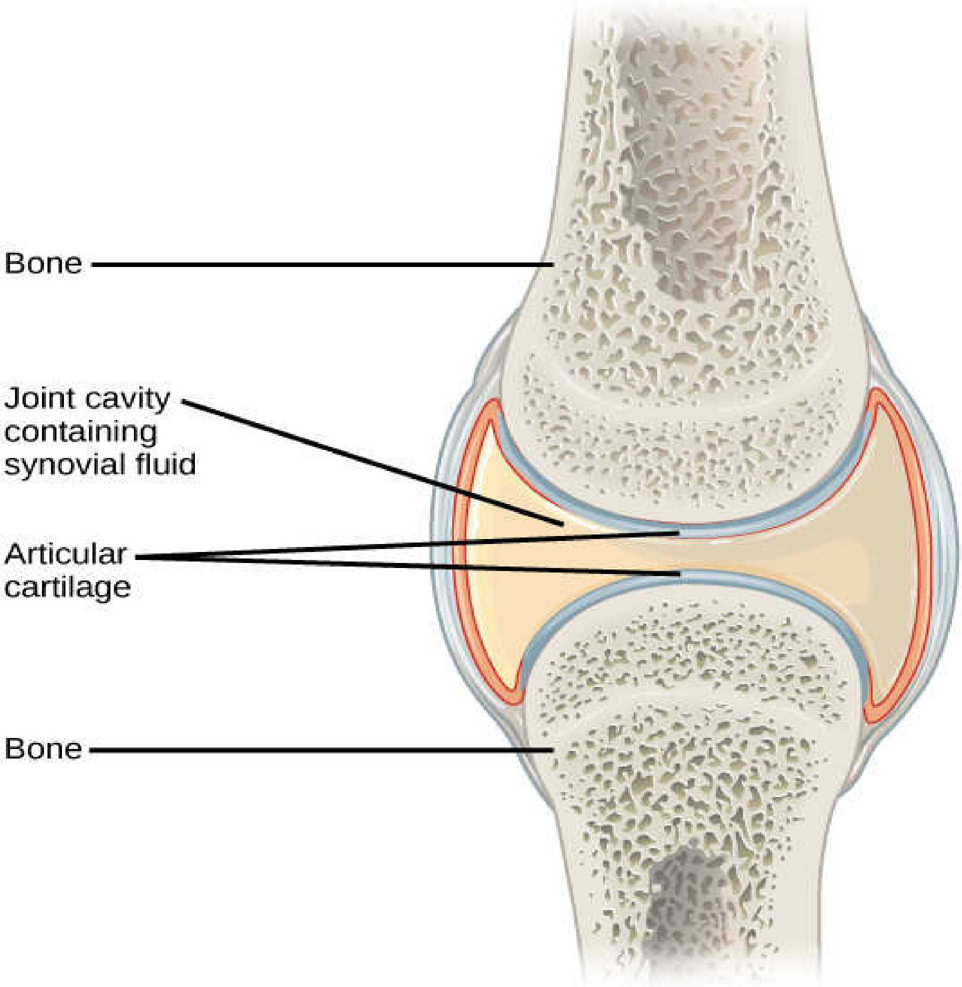
Some basic classifications of these sensory organs exist, but because not all afferent nerve fibers can be ascribed to one class exclusively, the classification remains relatively open (Johansson et al., 2000; Johansson et al., 1991). The distribution of these afferents differs between ligaments, joint capsules and cartilage structures (Figure 1). Ligaments have been most often the subject of research. In some, distribution of proprioceptors is homogenous throughout the length of the ligament, while in others most afferents are located near the ligament insertion to the bone (Johansson et al., 1991; Solomonow, 2006). As described by Solomonow (2006) there are two theories trying to explain the functional role of the diverse distribution of sensory afferents. As sensors in the bony insertions of ligaments are under lesser strain due to higher stiffness of surrounding tissue, their excitation threshold is elevated. As such, afferent excitation will be produced only at higher strains causing ligament elongation. Conversely, if afferents are evenly distributed in the ligament, this may indicate an ongoing service as a sensor for the detection of angle, position, load, joint velocity, etc.

These proprioceptors are not limited to ligaments exclusively. Basically four types of proprioceptors can be found in all soft tissues of joint. These are Golgi-like tendon organs, free nerve endings, Ruffini and Pacinian corpuscles (Johansson et al., 2000; Macefield, 2005; Solomonow, 2006). For a specific location of specific proprioceptors an extensive review is provided in literature (Johansson et al., 2000). An additional functional characteristic is the fast or slow adaptability to mechanical stress. Sensors that are slow adapting contribute sensory information during static positions as well as during slow movements.

	Primary Angular Motions	Mechanical Analogy	Anatomic Examples
Hinge joint	Flexion and extension only	Door hinge	Humero-ulnar joint Interphalangeal joint
Pivot joint	Spinning of one member around a single axis of rotation	Doorknob	Humeroradial joint Atlanto-axial joint
Ellipsoid joint	Biplanar motion (flexion-extension and abduction-adduction)	Flattened convex ellipsoid paired with a concave trough	Radiocarpal joint
Ball-and-socket joint	Triplanar motion (flexion-extension, abduction-adduction, and internal-external rotation)	Spheric convex surface paired with a concave cup	Glenohumeral joint Coxofemoral (hip) joint
Plane joint	Typical motions include slide (translation) or combined slide and rotation	Relatively flat surfaces apposing each other, like a book on a table.	Carpometacarpal joints (digits II to IV) Intercarpal joints Intertarsal joints
Saddle joint	Biplanar motion; spin between bones is possible but may be limited by interlocking nature of joint	Each member has a reciprocally curved concave and convex surface oriented at right angles to the other, like a horse rider and a saddle	Carpometacarpal joint of the thumb Sternoclavicular joint
Condyloid joint	Biplanar motion; either flexion-extension and abduction-adduction, or flexion-extension and axial rotation (internal-external rotation)	Mostly spheric convex surface that is enlarged in one dimension like a knuckle; paired with a shallow concave cup	Metacarpophalangeal joint Tibiofemoral (knee) joint

Clinicalgate.net.2020

Britanica.com.



Britanica.com.2021

4.0 CONCLUSION

Kinaesthetic sense is an important component of motor control system. Perception of limb and body position and movement enable planning oncoming and correcting ongoing movement. Perception is based on sensory information derived from specialized peripheral sensory organs called proprioceptors. These are located in various joint, muscle, tendon and coetaneous tissue. Their role is to convert mechanical stress in messages that can be understood by the central nervous system, which uses this information in process of movement planning, initiating and repairing. Main processing that is thought to be responsible for conscious perception of position and movement sense is thought to take place in the motor and sensory cortex. But same information is used by the cerebellum in unconscious motor programming as well.

Kinaesthetic sense has been correlated with sensory-motor deficiencies following injury and disease. Other effectors such as cold, stretching, fatigue, age and training experience have been shown to alter kinaesthetic acuity. Based on its relevance in movement control it became of interest to sports and medicine. Different kinaesthetic sense assessment methods have been developed. Specialized group of methods focuses on measuring the function of kinaesthetic underlying neuro-physiological mechanisms. These methods are useful for research and in-depth screening purposes, but are not appropriate for practical use in rehabilitation and sports. Second group of methods assesses kinaesthetic sense of voluntary and conscious perceived movements. Methods from this group are relatively simple to use, and are therefore appropriate for use in sports and rehabilitation settings.

Methods such as active and passive joint repositioning, sense of passive movement and sense of force represent this group. Tracking methods represent the third group. These methods can be used to upgrade previously described methods and combine individual tests. More functional sports testing can be performed using these methods. Partially, balance and equilibrium assessment methods can be used for kinaesthetic sense screening as well. Because these tests demand active motor reactions, outcomes of these tests are not solely a consequence of kinaesthetic acuity. In sports an interesting new insights into movement adaptation to fatigue and training is being studied using these methods. Effects of specific training modalities have been studied, but still data on its specific relevance for movement skill and sports performance are missing.

5.0 SUMMARY

Kinaesthesia takes five different perspectives on kinaesthesia, beginning with its evolution across animate life and its biological distinction from, and relationship to proprioception. It proceeds to document the historical derivation of "the muscle sense," showing in the process how analytic philosophers bypass the import of kinaesthesia by way of "inaction," for example, and by redefinitions of "tactical deception." The article then gives prominence to a further occlusion of kinaesthesia and its subduction by proprioception, these practices being those of well-known phenomenologists, practices that exemplify an adultism perspective supported in large part by the writings of Merleau-Ponty. Following this extended critical review, the article shows how Husserl's phenomenology enlightens us about kinaesthesia and in doing so offers us substantive clues to the phenomenology of learning as it takes place in the development and acquisition of skilful movement.

6.0 TUTOR – MARKED ASSIGNMENT

1. Explain the Joint structures and their sensory role.
2. Outline the Classification of Measurement Methods.

7.0 REFERENCES/FURTHER READING

Adkins, D., Boychuk, J., Remple, M., & Kleim, J. (2006). Motor training induces experience- specific patterns of plasticity across motor cortex and spinal cord. Journal of Applied Physiology, 101(6), 1776-82.

Alentorn-Geli, E., Myer, G., Silvers, H., Samitier, G., Romero, D., Lázaro-Haro, C., & Cugat, R. (2009). Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: Mechanisms of injury and underlying risk factors. Knee Surgery, Sports Traumatology, Arthroscopy, 17(7), 705-729.

Allegrucci, M., Whitney, S., Lephart, S., Irrgang, J., & Fu, F. (1995). Shoulder kinaesthesia in healthy unilateral athletes participating in upper extremity sports. The Journal of Orthopaedic and Sports Physical Therapy, 21(4), 220-226.

Alvemalm, A., Furness, A., & Wellington, L. (1996). Measurement of shoulder joint kinaesthesia. Manual Therapy, 1(3), 140-145.

Fischer, M., & Schäfer, S. (2005). Effects of changes in pH on the afferent impulse activity of isolated cat muscle spindles. Brain Research, 1043(1-2), 163-178.

Fonda, B., & Sarabon, N. (2010). Biomechanics of cycling: literature review. Sport Science Review, 19(1-2), 187-210.

Fong, S., & Ng, G. (2006). The effects on sensorimotor performance and balance with Tai Chi training. Archives of Physical Medicine and Rehabilitation, 87(1), 82-87.

Forkin, D., Koczur, C., Battle, R., & Newton, R. (1996). Evaluation of kinesthetic deficits indicative of balance control in gymnasts with unilateral chronic ankle sprains. The Journal of Orthopedic and Sports Physical Therapy.

UNIT 2 SKIN AND SENSORY FUNCTION

CONTENTS

1.0 INTRODUCTION

The skin acts as a sense organ because the epidermis, dermis, and the hypodermis contain specialized sensory nerve structures that detect touch, surface temperature, and pain. ... This rich innervation helps us sense our environment and react accordingly. The skin protects us from microbes and the elements, helps regulate body temperature, and permits the sensations of touch, heat, and cold. Skin has three layers: The epidermis, the outermost layer of skin, provides a waterproof barrier and creates our skin tone. Additionally, to muscle and joint sensory function, coetaneous sensory system has been shown to effect kinesthetic sense as well (Macefield, 2005; Rowe, Tracey, Mahns, Sahai, & Ivanusic, 2005).

2.0 OBJECTIVES

At the end of the studies the students will learned the following:

- The skin of human body.
- The sensory organ of human body.

3.0 MAIN CONTENT

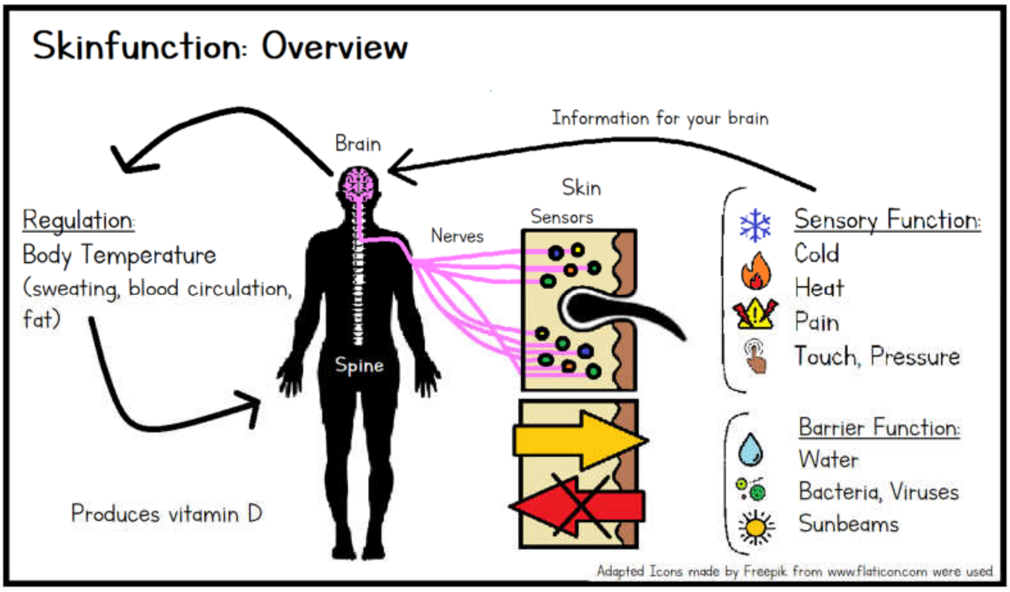
3.1 Skin

The skin acts as a sense organ because the epidermis, dermis, and the hypodermis contain specialized sensory nerve structures that detect touch, surface temperature, and pain. ... This rich innervation helps us sense our environment and react accordingly. The skin protects us from microbes and the elements, helps regulate body temperature, and permits the sensations of touch, heat, and cold. Skin has three layers: The epidermis, the outermost layer of skin, provides a waterproof barrier and creates our skin tone. Additionally, to muscle and joint sensory function, coetaneous sensory system has been shown to effect kinesthetic sense as well (Macefield, 2005; Rowe, Tracey, Mahns, Sahai, & Ivanusic, 2005). Basically these receptors are located in the skin, and differ between different coetaneous regions of the body. Basic types are Meissner and Pacinian corpuscles, Markels complex and Ruffini endings. As discussed previously, coetaneous receptors can affect the excitability of muscle spindle and as will be presented in the following test, can be more important than the muscle and joint receptors for the perception of a joint position.

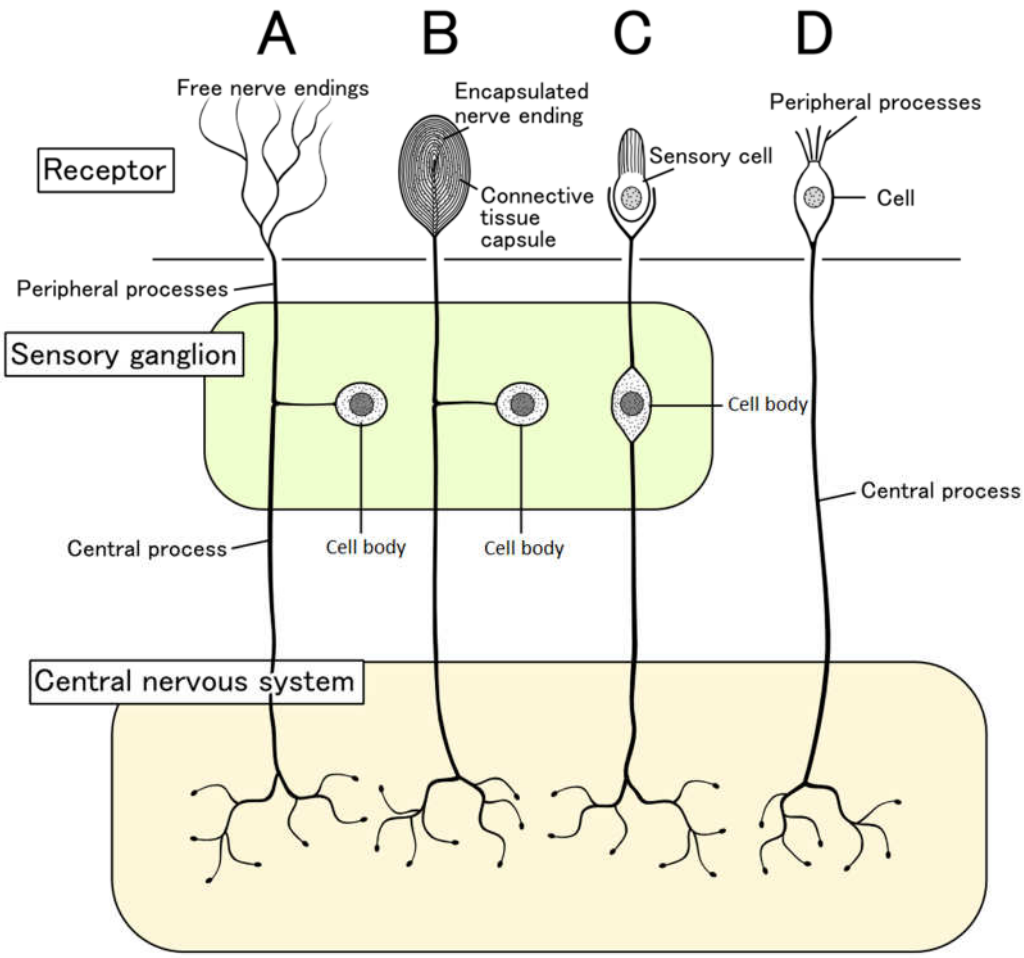
3.2 Neurological and Functional Background

As mentioned by sir Sherrington in the beginning of the 20th century, our body's poses specialized sensory organs called proprioceptors located in different peripheral tissue (Lephart et al., 2000). Most commonly described are joint-, muscle-, tendon- and cutaneous tissues. Proprioceptors are specially designed to be sensitive to certain types of mechanical stress like elongation, compression and increased pressure induced by the movement deformation (Morrissey, 1989; Young, Stokes, & Iles, 1987). There are also other types of sensors sensitive to chemical irritants, called nociceptors. Inflammation or intra-articular effusion usually stimulates their activity. This abundant sensory information is then sent via different ascending neural tracts to the higher levels of the neural system for processing (Kandel, Schwartz, & Jessell, 2000). Effects of the specific proprioceptive fields on movement have been studied mostly in rehabilitation studies. Anterior cruciate ligament has been given a lot of attention, because it affects reflexive knee stabilization (Johansson, Sjölander, & Sojka, 1991; Krogsgaard, Dyhre-Poulsen, & Fischer-Rasmussen, 2002). Similar function has been also suggested for the shoulder capsule (Myers & Oyama, 2008) in gleno-humeral movement. Other sensors located in the ligaments, menisci, tendons and skin, were shown to contribute to perception of joint angle and movement as well (Proske & Gandevia, 2009; Riemann & Lephart, 2002).

Basically these receptors are located in the skin, and differ between different coetaneous regions of the body. Basic types are Meissner and Pacinian corpuscles, Markels complex and Ruffini endings. As discussed previously, coetaneous receptors can affect the excitability of muscle spindle and as will be presented in the following test, can be more important than the muscle and joint receptors for the perception of a joint position.



Clinicalgate.net. 2000



The first level where sensory information is processed is the spinal cord. Clinicalgate.net. After reaching spinal level, sensory information is conducted to higher levels of the nervous system and motor information back to the muscles.

Most simple and most often described neural circuit is the stretch reflex. As the muscle spindle is excited by muscle stretch, it sends sensory impulses via afferent fibers that enter the spinal cord in the posterior horns of the spinal grey matter. There it connects via the synapse to the α-motor neuron and causes it to fire. The α-motor neuron and its branches terminate on muscle fibers that it innervates and causes muscle contraction (Enoka, 2008; Kandel, Schwartz, & Jessell, 2000). More complex neuronal connections are present, besides simple monosynaptic stretch reflex. Local networks can be divided in single- bi or oligo – synaptic loops, also called reflex loops. An example of bi-synaptic connection is the pre-synaptic inhibition, moreover the control of which by the higher nerve centers represents oligo-synaptic connectivity. Other examples of oligo-synaptic reflexes are cross extensor and withdrawal reflex. The bigger the number of synapses, the more complex is the reflex, and the bigger is the chance to be controlled by higher nervous structures. This first functional connectivity between sensory and motor connections is thought as a basic blueprint of simplest motor behavior. But their contribution to kinesthetic sensations is important as so far as the sensory information can be modified by mechanisms such as increased muscle spindle discharge.

The sensory information that is used for perception of kinaesthesia is transmitted via lateral dorsal tracts to the sensory cortex (Riemann & Lephart, 2002). There the information is supposed to be processed and enable perception of kinaesthetic senses (Naito, 2004). This information can be used by the motor controlling system to prepare and execute voluntary movement.

The information on current body posture, movement and orientation in space plays a considerable role in adapting ongoing movement to constraints of the environment. In motor control higher processing of sensory information is thought to contribute to most elaborate adaptations of movement. The comparison of the planed and actual movement enables the motor controlling system to prepare correction of the following movement or prepare new ones.

Based on the time constrain rationale kinesthetic sensation cannot directly contribute to open loop control or to fast adaptations of movement. Although kinesthetic sense is thought to demand time, and is not fast enough to contribute to faster movement corrections, this might not be the case. Perceived change in body posture can influence fast open loop movement adaptations.

Due to such information, the motor controlling system is able to adapt to the otherwise fast and by kinaesthetic sense unaffected motor responses. An example can be the adaptation of a cyclist’s leg musculature during steep uphill riding (Fonda & Sarabon, 2010). Other specific adaptations to perception of body posture or limb position on motor output have been shown (Knikou, 2005; Niessen, Veeger, & Janssen, 2009).

When mechanical stress is applied to the joint, proprioceptors are excited according to their responsiveness to a specific mechanical stress and the tissue being stressed. Experiments performing tension on ligaments in animal models have shown that sensory information from stressed ligaments starts firing as ligaments are stressed 4-5% of their maximal strain (Holden et al., 1994). This data lines up with the outcomes of studies that measured the strain put on ligaments during walking. The sensory subsystem is extremely sensitive and starts firing already during the support phase of walking, where knee ligaments can be stressed up to 6% of their maximal strength (Henning, Lynch, & Glick, 1985; Johansson et al., 2000), suggesting that ligaments produce sensory information during less demanding activities.

There is some evidence that the proximal joints (the shoulder) have lower thresholds for movement detection when compared to the distal joints (the elbow and most distal inter-phalangeal joints) expressed in degrees of movement until movement detection (Proske, 2006; Tripp, Uhl, Mattacola, Srinivasan, & Shapiro, 2006). This suggests a difference in the sensory function between proximal and peripheral joints. Proximal joints have a specific role from the perspective of force production as well as from perspective of movement accuracy affecting the positioning and movement of distal segments. They are the beginning of the kinetic chain producing power and represent the spatial ground base for the distal joints. As the movement continues in more distal joints, their function is to produce velocity of the movement, and compensate for the possible spatial error in positioning of proximal joints. Possible compensations can cause distal joints to be active in a wider range of motion. For example, the torso and shoulder joint must be positioned as accurately as possible when a subject is trying to hit tennis- or a volleyball ball. Elbow joint and wrist must compensate for possible but small errors of the trunk and shoulder positioning. This small errors result in adaptive movements performed through a wider range of motion in the distal joints (Tripp et al., 2006). The discussion on the importance of cutaneous receptors in kinaesthesia is still in progress. In their review Proske and Gandevia (2009) argue that sensory information derived from multi-articular muscles on single joint position and movement is rather ambiguous. Cutaneous information aids muscle spindle to detect joint specific movements. This has been shown in the fingers, where the stretching of the skin proved to be of importance for detecting joint position.

Certain factors such as cold, fatigue, vibration, injury, disease and training have been shown to effect kinaesthesia. Their influence can substantially influence the ability to correctly perceive joint position and alter motor control. In sports, injury might develop as a consequence of the inability to perceive incorrect body alignment, movement and posture. This can sometimes result in an injury (Myers & Oyama, 2008). Environmental factors such as decreased temperatures or cryotherapy can affect kinaesthesia as well as sensory-motor function. As reported by Uchio et al. (2003) the nerve conduction velocity after cryotherapy is reduced. Moreover, sensory-motor control can be affected by cryotherapy (Wassinger, Myers, Gatti, Conley, & Lephart, 2007), possibly resulting in reduced joint stability. However, there is controversial evidence regarding the effect of cooling the tissue has on the joint position sense (Costello & Donnelly, 2010).

The relevance of the cold on conditioning kinesthetic sense remains a matter of debate. Based on the mentioned reports, more specific guidelines to the athletes and their coaches, for now, cannot be given. In sports, fatigue is a constant companion of continuous and strenuous activities. The description of fatigue is basically based on the definition of a decreased ability to sustain production of the desired force (Gandevia, 2001; Gandevia, Enoka, McComas, Stuart, & Thomas, 1995). On the other hand, fatigue can cause other changes in the sensory-motor function as well, as it influences the sensory function. Fatigue can develop at the periphery or centrally in the central nervous system (Gandevia et al., 1995; Sacco, Thickbroom, Byrnes, & Mastaglia, 2000; Sacco, Thickbroom, Thompson, & Mastaglia, 1997).

The causes of a compromised sensory drive are multiple. Changes can be due to muscle metabolites that can affect muscle spindle activity (Djupsjöbacka, Johansson, & Bergenheim, 1994; Fischer & Schäfer, 2005), changes in sensory relevant contribution of specific mechanoreceptors in the joint (Tripp, Yochem, & Uhl, 2007a, 2007b) or central changes (Miura et al., 2004). Many studies considering the effect of fatigue on kinaesthetic sense were performed on the shoulder girdle and on the knee. Different fatiguing protocols induced decreased joint position acuity due to altered sensory-motor function of the exposed limbs. Adaptations to training different training modalities have been shown to affect kinaesthetic sense.

Most often effects of sensory-motor training (i.e. exercises requiring balance and functional joint stability activities) have been reported (Taube, Gruber, & Gollhofer, 2008).

As shown by Tripp, Faust, and Jacobs (2009) tracking predefined movement with online feedback and vibrations applied to the hand improved kinaesthesia. Fong and Ng (2006) and Wooton (2010) showed that a long-term practice of tai-chi can influence kinaesthesia as well. Without doubt most frequently used modality is sports technique training. Posing awareness on the movement performed, kinaesthetic sensations are thought to be additionally stressed and refined. In practice, a superior sensory-motor function was observed in expert athletes compared to non-athletes (Vuillerme, Teasdale, & Nougier, 2001). Research, however, presents no beneficial effects of expertise on kinesthetic sense (Freeman & Broderick, 1996; Kioumourtzoglou, Derri, Mertzanidou, & Tzetzis, 1997). Some authors even suggest that specific effects of sports training might even decrease kinaesthetic sense (Allegrucci, Whitney, Lephart, Irrgang, & Fu, 1995). Others, however, present evidence that experienced athletes poses superior awareness of movement, incorporating sports specific tools like rackets (Fourkas, Bonavolontà, Avenanti, & Aglioti, 2008). In the future, more task specific oriented studies are needed to illuminate the specific adaptations of kinaesthetic awareness to specific sports.

Central adaptations have been proven as a consequence of balance and skill training. It was shown that cerebral areas become less active in well adopted movements, suggesting an increased involvement of sub-cerebral centres (Taube et al., 2008). When novel movement strategies are demanded, the activity of cerebral centres increases, causing remodulation of the already established connections and movement strategies (Adkins, Boychuk, Remple, & Kleim, 2006; Boniface & Ziemann, 2003). This suggests that novel movement tasks should be used to cause re modulation of the already acquired but inappropriate movement strategies. Specifically, sensory information is less probable to be altered as a result of training (Ashton-Miller, Wojtys, Huston, & Fry-Welch, 2001).

As argued by Ashton-Miller et al. (2001) central changes in processing of sensory information are more probable to take place, enabling more efficient awareness and perception. From the functional point of view, these changes are shown in improved balance, joint stability, intramuscular coordination, muscle strength, kinaesthetic sense and jumping ability.

This can be important in skills where precise manipulation of hand-held objects is important. Moreover, cutaneous receptors are an important source of information to perceive body sway (Fukuoka, Nagata, Ishida, & Minamitani, 2001).

As proposed by Schweigart and Mergner (2008) and Turvey (2007) information used to perceive body movement and position can vary according to the de- minds and availability of different sources of sensory information. This enables adaptability of the sensory system that provides us with the relevant information. Factors affecting kinaesthesia. Certain factors such as cold, fatigue, vibration, injury, disease and training have been shown to effect kinaesthesia.

Their influence can substantially influence the ability to correctly perceive joint position and alter motor control. In sports, injury might develop as a consequence of the inability to perceive incorrect body alignment, movement and posture. This can sometimes result in an injury (Myers & Oyama, 2008). Environmental factors such as decreased temperatures or cryotherapy can affect kinaesthesia as well as sensory-motor function.

As reported by Uchio et al. (2003) the nerve conduction velocity after cryotherapy is reduced. Moreover, sensory-motor control can be affected by cryotherapy (Wassinger, Myers, Gatti, Conley, & Lephart, 2007), possibly resulting in reduced joint stability. However, there is controversial evidence regarding the effect of cooling the tissue has on the joint position sense (Costello & Donnelly, 2010). The relevance of the cold on conditioning kinaesthetic sense remains a matter of debate. Based on the mentioned reports, more specific guidelines to the athletes and their coaches, for now, cannot be given.

In sports, fatigue is a constant companion of continuous and strenuous activities. The description of fatigue is basically based on the definition of a decreased ability to sustain production of the desired force (Gandevia, 2001; Gandevia, Enoka, McComas, Stuart, & Thomas, 1995). On the other hand, fatigue can cause other changes in the sensory-motor function as well, as it influences the sensory function. Fatigue can develop at the periphery or centrally in the central nervous system (Gandevia et al., 1995; Sacco, Thickbroom, Byrnes, & Mastaglia, 2000; Sacco, Thickbroom, Thompson, & Mastaglia, 1997). The causes of a compromised sensory drive are multiple.

Changes can be due to muscle metabolites that can affect muscle spindle activity (Djupsjöbacka, Johansson, & Bergenheim, 1994; Fischer & Schäfer, 2005), changes in sensory relevant contribution of specific mechanoreceptors in the joint (Tripp, Yochem, & Uhl, 2007a, 2007b) or central changes (Miura et al., 2004).

Many studies considering the effect of fatigue on kinaesthetic sense were performed on the shoulder girdle and on the knee. Different fields of research and practice have provided the methodology used for the assessment of kinesthetic sense (Chung, Cho, & Lee, 2006; DeMyer, 2004; Gandevia & McCloskey, 1976; Kelley, 1969; Koerth, 1922; Kurillo, Gregoric, Goljar, & Bajd, 2005; Tripp et al., 2007a). Based on the nature of various approaches, methods can be organized in two main categories (Table 1). First category includes tests that are specialized in assessing electrophysiological functions of mechanisms underlying kinesthesia (Knikou, 2008; MacDonald & Paus, 2003; Misiaszek, 2003; Roland, 1987; Roland & Mortensen, 1987; Ruohonen & Karhu, 2010; Tibone, Fechter, & Kao, 1997; Zehr, 2002). These tests incorporate different neurophysiologic methods that are usually reserved for medical assessment and research, and therefore we paid no special attention to it in this paper. The second group includes methods that are focused on assessing kinesthesia in the context of voluntary and consciously perceived movement (Chung et al., 2006; Gandevia & McCloskey, 1976; Koerth, 1922). This class can be further subdivided into methods for assessing sense of joint or limb position, sense of movement, force, effort and tracking tests. A nonspecific element of this group is balance testing that cannot be exclusively considered as kinesthesia measurement technique. But these methods do provide some insight into the functional perspective of balance, where kinesthetic sense plays an important role (Benvenuti, 2001; Winter, Patla, Prince, Ishac, & GieloPerczak, 1998). It is important for kinesthesia measuring methodology to enable progression from basic towards more functional testing (Cates & Cavanaugh, 2009). Basic measures focus on individual subsystems or simple isolated movements (Kurillo et al., 2005). Measures of specific neurophysiologic functions or kinaesthesia of isolated joints should be the methods of choice. In rehabilitation and sports, progression toward functional assessment is warranted, for providing the insight into the functional movement aspect of kinaesthesia (Chung et al., 2006). These provide qualitative data on the rehabilitation or training progression as well as on the extent of deterioration after injury or disease (Cates & Cavanaugh, 2009; Chung et al., 2006; Kurillo et al., 2005). Similar testing movements can be used in different measurement techniques. Some methods are simpler to use, because they do not use specialized equipment. For example, clinical neurological examinations of sensory function usually include reports of appropriate perception of movement direction of a passively moved finger or a limb (DeMyer, 2004). Other methods apply sophisticated technology enabling more precise measures of different movement characteristics. For example, precise measures of individual joint angles enable quantification of kinaesthetic sense as well as expressing its importance as a part of a functional multi-joint unit (Tripp et al., 2006). Another illustrative example can be drawn from balance assessment methods. Simple time measures of ability to sustain in balance can be upgraded with specialized equipment, enabling measuring of body sway (Le Clair & Riach, 1996; Tyson & Connell, 2009). With it, an important insight into the hidden but important effects of specific kinaesthetic components on motor behavior is possible (Krishnamoorthy, Yang, & Scholz, 2005).

4.0 CONCLUSION

Sense is an important component of motor control system, perception of limb and body position and movement enable planning oncoming and correcting ongoing movement. Perception is based on sensory information derived from specialized peripheral sensory organs called proprioceptors. These are located in various joint, muscle, tendon and coetaneous tissue. Their role is to convert mechanical stress in messages that can be understood by the central nervous system, which uses this information in process of movement planning, initiating and repairing. Main processing that is thought to be responsible for conscious perception of position and movement sense is thought to take place in the motor and sensory cortex. But same information is used by the cerebellum in unconscious motor programming as well. Sense organ has been correlated with sensory-motor deficiencies following injury and disease. Other effectors such as cold, stretching, fatigue, age and training experience have been shown to alter kinaesthetic acuity. Based on its relevance in movement control it became of interest to sports and medicine. Different kinaesthetic sense assessment methods have been developed. Specialized group of methods focuses on measuring the function of sense underlying neuro-physiological mechanisms. These methods are useful for research and in-depth screening purposes, but are not appropriate for practical use in rehabilitation and sports. Second group of methods assesses kinaesthetic sense of voluntary and conscious perceived movements. Methods from this group are relatively simple to use, and are therefore appropriate for use in sports and rehabilitation settings. Methods such as active and passive joint repositioning, sense of passive movement and sense of force represent this group. Tracking methods represent the third group. These methods can be used to upgrade previously described methods and combine individual tests. More functional sports testing can be performed using these methods. Partially, balance and equilibrium assessment methods can be used for kinaesthetic sense screening as well. Because these tests demand active motor reactions, outcomes of these tests are not solely a consequence of kinaesthetic acuity. In sports an interesting new insights into movement adaptation to fatigue and training is being studied using these methods. Effects of specific training modalities have been studied, but still data on its specific relevance for movement skill and sports performance are missing.

5.0 SUMMARY

Sense is an important component of motor control system, perception of limb and body position and movement enable planning oncoming and correcting ongoing movement. Perception is based on sensory information derived from specialized peripheral sensory organs called proprioceptors. These are located in various joint, muscle, tendon and coetaneous tissue. Their role is to convert mechanical stress in messages that can be understood by the central nervous system, which uses this information in process of movement planning, initiating and repairing. Main processing that is thought to be responsible for conscious perception of position and movement sense is thought to take place in the motor and sensory cortex. But same information is used by the cerebellum in unconscious motor programming as well.

6.0 TUTOR – MARKED ASSIGNMENT

1. Draw the skin of human body.
2. Explain sensory organ of human body.

7.0 REFERENCES/FURTHER READING

Adkins, D., Boychuk, J., Remple, M., & Kleim, J. (2006). Motor training induces experience- specific patterns of plasticity across motor cortex and spinal cord. Journal of Applied Physiology, 101(6), 1776-82.

Alentorn-Geli, E., Myer, G., Silvers, H., Samitier, G., Romero, D., Lázaro-Haro, C., & Cugat, R. (2009). Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: Mechanisms of injury and underlying risk factors. Knee Surgery, Sports Traumatology, Arthroscopy, 17(7), 705-729.

Allegrucci, M., Whitney, S., Lephart, S., Irrgang, J., & Fu, F. (1995). Shoulder kinaesthesia in healthy unilateral athletes participating in upper extremity sports. The Journal of Orthopaedic and Sports Physical Therapy, 21(4), 220-226.

Alvemalm, A., Furness, A., & Wellington, L. (1996). Measurement of shoulder joint kinaesthesia. Manual Therapy, 1(3), 140-145.

Fischer, M., & Schäfer, S. (2005). Effects of changes in pH on the afferent impulse activity of isolated cat muscle spindles. Brain Research, 1043(1-2), 163-178.

Fonda, B., & Sarabon, N. (2010). Biomechanics of cycling: literature review. Sport Science Review, 19(1-2), 187-210.

Fong, S., & Ng, G. (2006). The effects on sensorimotor performance and balance with Tai Chi training. Archives of Physical Medicine and Rehabilitation, 87(1), 82-87.

Forkin, D., Koczur, C., Battle, R., & Newton, R. (1996). Evaluation of kinesthetic deficits indicative of balance control in gymnasts with unilateral chronic ankle sprains. The Journal of Orthopedic and Sports Physical Therapy.