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Comprehensive gait analysis as an assessment tool of Patello- femoral Pain Syndrome in runners

Walking and running gait guidebook for
physiotherapy students

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ABSTRACT

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This thesis touches upon the use of gait analysis as an assessment method for runners' knees, also known as Patellofemoral pain syndrome. The aim is to explore and evaluate the current evidence and literature about the use of gait analysis in runners with Patellofemoral pain syndrome. Literature compiled surrounding this topic was used to develop assessment competency in physiotherapy students due to a lack of formal and in-depth education in gait analysis, by creating a comprehensive guidebook.

The theoretical model for this thesis, implemented in the guidebook, was based on current theoretical literature and research articles. To review and evaluate all collected literature involved in the theoretical basis, an integrative review was conducted to formulate relevant themes pertaining to the topic of gait analysis in patellofemoral pain syndrome. Based on the thematic division from the integrative review, a guidebook was created via the platform Canva and distributed to current physiotherapy students of SAMK, where feedback was collected wherein it reflected on its effectiveness and quality.

Results from the integrative literature review concluded a lack of evidence and consensus around the usability of visual/ observational gait analysis to assess the vague appearance of Patellofemoral pain syndrome. However, it suggested moderate evidence on the existence of overall gait characteristics associated with it in walking and running conditions. The guidebook yielded positive feedback for its content, outcome, usability, and its quality of its overall effectiveness.

In addition to the outcome, literature suggested uncertainty in understanding the nature of these gait presentations as author suggested a full implementation of the action research model to further improve and develop methods in utilizing gait analysis in applicable settings.

In conclusion, the use of gait analysis for patellofemoral pain syndrome in runners should be included in a complete comprehensive assessment of the injury, to consider the multifactorial nature of this overuse/ overload knee injury.

Keywords: Patellofemoral Pain syndrome, gait analysis, running, differential diagnosis, walking gait, running gait, running biomechanics, gait kinetics, gait kinematics, temporal-spatial parameters, observational gait analysis, instrumented gait analysis, physiotherapy assessment.

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LIST OF SYMBOLS AND TERMS

PFPS= Patellofemoral Pain Syndrome

PFJ= Patellofemoral Joint

PFJRF= Patellofemoral Joint Reaction Force

Gait

Gait Cycle

Gait Kinetics

Gait Kinematics

TSPs= Spatiotemporal parameters

GRF= Ground reaction force

COG= Centre of gravity

COM= Centre of Mass

BW= Body weight

1 INTRODUCTION

Patellofemoral pain syndrome (PFPS) is a broad musculoskeletal condition, wherein typical physical examinations often show subtle signs that may not always produce the same exact features of it based off current literature (Kasitinon et al., 2021). PFPS is considered one differential diagnosis under the umbrella of Anterior knee pain for pain associated with overuse and overload injuries. It is currently diagnosed through a process of excluding other pathologies and injuries associated with Anterior knee pain (Bump, 2023). Unfortunately, due to its vague presentation, based on current observations and evidence, recurrence rate of PFPS is between 70-90% in which factors contributing to its deposition are not well established (Davis & Powers, 2010), reflecting its challenges in management and rehabilitation. Additionally, discussion about etiological factors of PFPS, is suggested to be multifactorial, in addition to training errors as secondary factors (Bump, 2023). Management of running injuries are sometimes evaluated through an assessment of running and ambulatory techniques to assess such secondary factors as previously stated. This is also known as Gait analysis. Gait is a functional assessment method that physical therapists use “to determine gait abnormalities, assess injuries, or help athletes achieve recovery or performance goals.”, as defined by Taggart (2022). It has multiple discourses about the relevancy of it utilized in addressing overuse and overload injuries within the athletic population specifically in the activity of running.

Current evidence suggests that gait is under observed in musculoskeletal injuries and pathologies where observational gait analysis shows moderate reliability in practical use (Brunnekreef et al., 2005). Therefore, this thesis explores whether functional assessment tools such as gait analysis could be utilized as a differential diagnostic tool, or a valuable means to evaluate PFPS. In respects to this, using associated findings with formulating different priorities

in physiotherapeutic treatment of PFPS, insights on injury mechanisms, and prioritization within rehabilitation plan, gait analysis may be of value in the clinical reasoning process. Therefore, there is a need to increase and widen the understanding of gait, specify competency in gait analysis for physiotherapists to assess certain knee pain pathologies in musculoskeletal cases such as the common PFPS especially with training athletes.

In depth education to gait analysis is lacking in current curriculum for a bachelor's study in physiotherapy, especially in musculoskeletal pathologies and injury assessment. Therefore, this thesis devises, explores, and evaluates different methodologies to approach gait analysis in runners with PFPS.

2 AIMS AND OBJECTIVES

The aim of this thesis is to explore the utilization and evaluate the effectiveness of both walking and running gait as an assessment tool for PFPS based on current findings associated with its characteristics. This focuses on exploring its usability as a tool in differential diagnosis and injury management to address alarming recurrence rates on the sporting individual. Additionally, by opening the topic of its usefulness and value in knee rehabilitation of PFPS, the author seeks to derive insightful questions to develop further reliable and valid methodology in observational gait analysis in the future.

Therefore, the objective of this thesis will be put into practice, through creating a gait guidebook for physiotherapy students of SAMK to utilize through clinical reasoning and during clinical practice. It includes practical aspects through theoretical and empirical knowledge on the method of gait analysis applied to PFPS. The guidebook will touch on different modalities and methods of gait analysis but focuses on guidance in observational gait analysis specifically related to PFPS to support students' clinical reasoning process. The expected outcome in the distribution of this product is to increase competency in gait

analysis for physiotherapy students and entry level physiotherapists students within musculoskeletal physiotherapy of the lower extremity to develop clinical reasoning skills involved with the management of Patellofemoral Pain syndrome.

As the target audience for such a product is for the physiotherapy students of SAMK, this product is ordered by SAMK.

3 PATELLOFEMORAL PAIN SYNDROME

Patellofemoral pain syndrome (PFPS) or anterior knee pain comes from the phenomena of pain occurring in the patellofemoral joint (PFJ). The main characteristic of this knee pathology is the occurrence of chronic knee pain in different movements and activities. PFPS is a broad term used nowadays to classify anterior knee pain, amongst a collection of pathologies associated with knee pain whether at the anterior aspect. It is the most common injury within the running athlete population, amongst which contributes from 16 to 25 percent of all injuries diagnosed in runners. (Dixit, 2007.)

Within the athletic running population, women are 2.23 times more likely to develop PFPS in comparison to their male counterparts and it showed with the incidence rate of PFPS and its diagnosis. What is often seen is that PFPS occurs within individuals between the ages 15-30 years, affecting predominantly physically active adolescents to young working aged adults. (Boling et al., 2010.)

3.1 Associated risk factors and etiology

Etiology of PFPS relates back to its anatomical and physiological risk factors. The most typical and practical cause for PFPS is its association with overuse injuries and overload injuries. As described earlier, there are multiple risk factors that are associated with the occurrence of PFPS, which makes PFPS a multi factorial injury/ condition (Lankorst et al, 2012). The two most significant

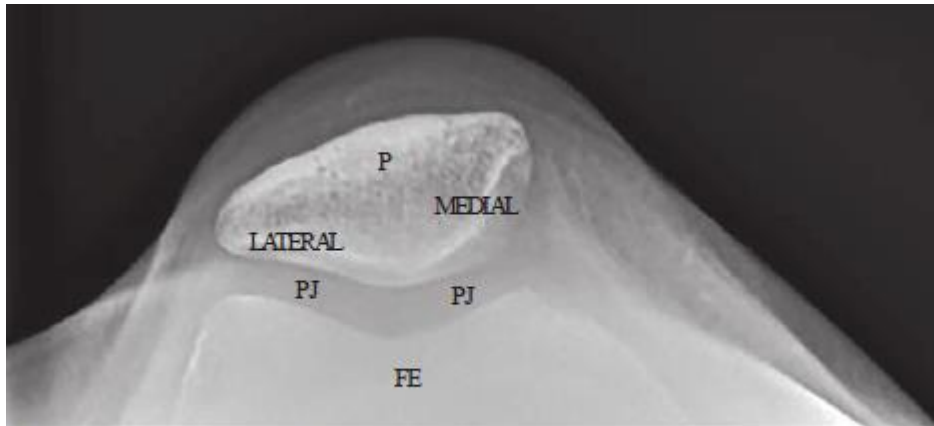
predisposers of PFPS symptoms are said to be the overload of the patella and its maltracking during movement (Yang et al, 2020).

According to a systematic review in 2012 by Lankorst et al., results showed that a possible risk factor related to PFPS is the occurrence of weaker strength in knee extension that is evident through peak torque. Some other factors derived were coordination and timing of vastus medialis and vastus lateralis activation, atypical anatomical structure, strength, and associated kinematic factors of which currently have conflicting evidence. (Lankorst et al., 2012.)

Likewise, some possible anatomical and physiological risk factors associated with PFPS are biomechanical stress, quadriceps weakness, VMO delayed activation, over pronation of the foot, hip weakness, and flexibility or inflexibility of related structures (Sisk & Fredericson, 2019).

3.2 Relevant anatomy of the knee in PFPS: The patellofemoral joint(PFJ)

PFPS is associated with symptoms that diverge from the PFJ. The PFJ is the junction between the patella and the femoral groove where it rests. The posterior aspect of the patella that is convex is covered in hyaline cartilage, allowing it to glide and move smoothly in accordance with the femoral trochlea with the aid of synovial fluid produced. The fit is conveyed in Picture 1. It is the biggest sesamoid bone in the human body and often fits differently between different individuals. This complex aspect influences how surrounding structures work together to act on the function and movement of the patella. (Loudon, 2016.)



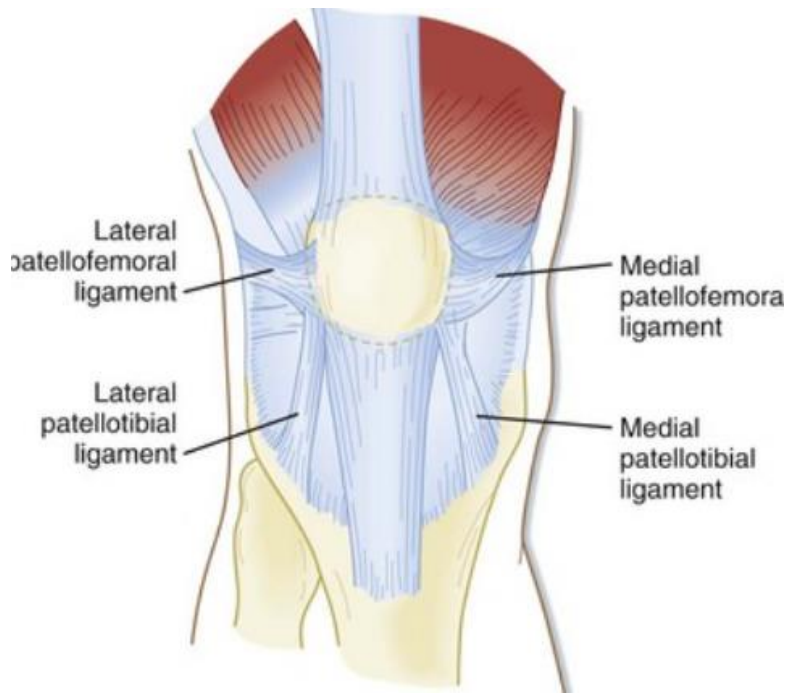
B. Skyline (Merchant) View (Knee in Flexion)

Picture 1: Fit of the left patella in the femoral trochlea (Ectors et al, 2018, p.2).

3.3 Relevant anatomy of the knee in PFPS: Main actors of the patella

I. Static actors

Stability of the PFJ is acted upon by ligaments, the patellar tendon, and the joint capsule. On the medial side of the knee, structures like the medial patellofemoral ligament, and the medial meniscopatellar ligament prevent the patella from deviating laterally. On the lateral side, the lateral patellofemoral ligament, lateral retinaculum, as well as the iliotibial band, and joint capsule functions to prevent medial deviation of the patella. (Loudon, 2016.) The structure of the PFJ and patellotibial ligaments are visualized in Picture 2.



Picture 2: Patellar ligaments (Physiopedia: Patellofemoral Joint, 2023).

II. Dynamic actors

The knee joint functions and performs extension using the patella as a pulley inducing stress at different moments of the whole range of the knee on ligaments attached. It undergoes flexion, through the function of the hamstring muscle group with the biceps femoris as a stabilizing factor. Extension occurs when the quadricep muscles (Vastus medialis, Vastus lateralis, Vastus intermedius, and rectus femoris) do mechanical work. The quadricep muscles extend the knee joint by pulling the patella upwards the femoral groove which is also attached by the patellar ligament at the tibial tuberosity. During this phase as the direction of force changes along the extension movement, the further involved the patella is. During flexion where hamstring muscles take over, it directs the patella downwards towards the joint line of the tibiofemoral joint with the support of the patellar tendon. (Loudon, 2016.)

During open chain flexion, the patella alignment follows that of the tibia, as during open chain extension, where it follows the tibia in its externally rotated position to fit itself into the trochlear groove. However, during closed chain movements, the patella is aligned in accordance with the rotational and horizontal plane motion of the hip. (Loudon, 2016.)

Patellar movement can deviate depending on the balance of quadriceps muscle function. For an example it can present itself in patellar maltracking where “the patella is abnormally positioned at 1 or more points in flexion-extension cycle” according to Wilson (2007). Patellar maltracking has been said to be a common finding in individuals diagnosed with PFPS (Petersen et al., 2013).

3.4 Patellofemoral Joint reaction force (PFJRF)

To understand patellar overload injuries such as PFPS, there is a need to understand the joint reaction force at the PFJ complex. The patellofemoral joint reaction force reflects the cumulative compression force impacting the PFJ complex during movement. This cumulative compression force is influenced by the joint angle of the knee as well as the corresponding muscle tension. The degree of stress placed on the PFJ is reflected through the PFJRF and its corresponding surface contact between the patella adjacent to the femur. The larger the surface contact is, the less surrounding soft tissue structures are involved. Surface contact increases as flexion angles increase in open chain movements. In closed chain movements, the PFJRF increases between 90-45 degrees of flexion and reduces at the end range of knee extension. (Loudon, 2016.)

3.5 PFPS and pain characteristics

PFPS is associated with worsening of pain during situations where the knee is not in a fully extended position, for example running, squatting, walking stairs, and sitting (Bump, 2023). Especially during circumstances where the knee is loaded in flexed positions (DY. Gaitonde, 2019).

Between individuals with PFPS, it is typically challenging to pinpoint the exact location in which the pain occurs. However, in many cases, it can be described as an achy or sharp pain surrounding the patella or underneath it. PFPS can occur in both knees or one, and pain may appear gradually or suddenly. (Bump, 2023.)

3.6 Differential Diagnosis and current physiotherapy guidelines

Some knee pathologies associated with anterior knee pain that are differentiated from PFPS include patellar and quadriceps tendinopathy, bursitis, saphenous neuritis, patellofemoral osteoarthritis, plica, referred pain from the hip or the lower back, and Osgood's Schlatter's disease (Bump, 2023).

Based on current clinical practice guidelines, diagnostic criteria for PFPS are solely based on the occurrence of peripatellar or retropatellar pain, pain that is aggravated in situations where the PFJ is loaded while flexed, and through a process of eliminating other anterior knee pain pathologies as well as tibiofemoral pathologies. These can be differentiated by performing a squat, or/and other "functional activities that load the PFJ in a flexed position." (Willy et al., 2019.)

Current clinical practice guidelines recommend therapeutic exercises targeting the hip and knee in pain management and developing functional capacity. More specifically posterolateral hip structures in the early phase of rehabilitation, and then added knee exercises. In the occurrence of over pronated feet, a foot orthosis may be prescribed and used to reduce pain temporarily. Kinesio taping adapted to the patella may be utilized during the early phase of rehabilitation to reduce pain in combination with therapeutic exercise for quicker results. Standalone manual, bioagent, needling, therapies are generally not recommended, as well as the use of patellofemoral knee orthoses. Ultimately, the combination of exercise therapy mixed with other physiotherapeutic interventions shows superior patient and treatment outcomes. (Willy et al., 2019.)

4 GAIT AND ITS RELATION TO THE MUSCULOSKELETAL SYSTEM

The definition of gait according to Mariam-Webster is "a manner of walking or moving on foot". Gait requires intact functioning of the nervous, the

musculoskeletal, and similarly the cardiopulmonary systems that are involved in locomotion. (Pirker & Katzenschlager, 2016.) Therefore, gait may be disturbed through impairment or changes in any of the stated functions due to secondary factors associated with them (Ataullah & De Jesus, 2024). For example, specific to musculoskeletal instances regarding pain along the lower body, one of the more prevalent gait discrepancies related to pain is an antalgic gait. An antalgic gait refers to a discrepancy in gait that is provoked through pain, often occurring in the lower back or lower extremity, that may present itself in the form of a limp when walking that is noticeable to the visible eye. (Auerbach & Tadi, 2023.) Other forms of gait discrepancies that may be related to the musculoskeletal system may include the Trendelenburg gait, leg length discrepancy, hip circumduction, in addition to the posterior lurch gait (Physio-pedia, Gait Deviations, 2024).

4.1 Walking gait cycle

Walking occurs in a cycle, and this is referred to as the gait cycle. The definition of the gait cycle is “the time interval between two successive occurrences of one of the repetitive events of walking” according to Levine et al., (2012).

Altogether the cycle is separated into 2 main phases: stance and swing phase. During the stance phase, a foot sustains contact with the ground, which is split into, initial contact, the loading response, Mid-stance, terminal stance, and Pre-swing. Subsequently, the swing phase refers to the duration in which the same foot that came from stance, is off contact with the ground and can be subdivided into: the initial swing, mid-swing, and terminal swing as visualized in Figure 1. During a full gait cycle, further divisions of actions occur in the lower extremity, in order from the start of the stance phase. These actions in chronological order are referred to as: initial contact, opposite toe off, heel rise, opposite initial contact, toe off, feet adjacent, tibia vertical. As the cycle repeats itself through these kinematic actions. (Levine et al., 2012, pp.32-33.)

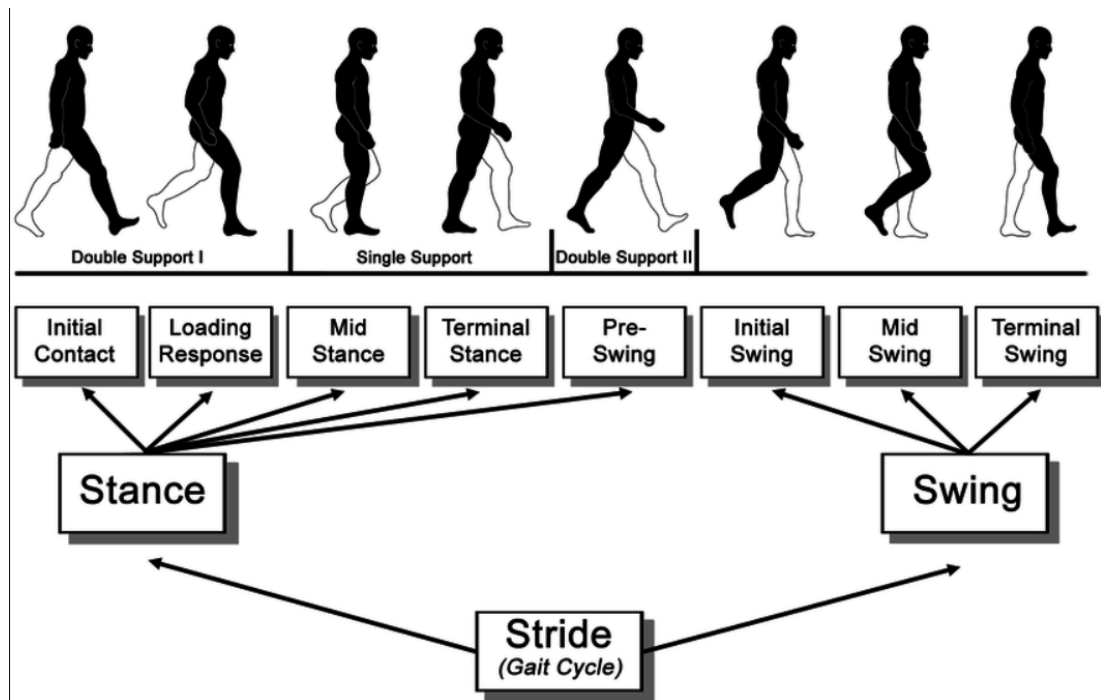


Figure 1: The walking gait cycle (Cicirelli et al, 2021).

4.1.1 Kinematics and the walking gait

According to Kapri et al (2021) “running kinematics is the description of motion characteristic such as position, velocity & acceleration of the lower extremities during the running cycle.” In a nutshell, kinematics measures joint displacement, velocity and acceleration during movement and is an essential part of movement analysis. Lower extremity kinematics are typically described through joints angles throughout the gait cycle.

At the start of the walking gait cycle, heel strike, the hip flexes approximately 25° - 30° , and extends when the foot is flat against the ground. Right before toeing off the hip extends 10° - 20° . The hip adducts maximally during stance as the foot lies flat against the floor and abducts during the swing phase. The pelvis orients from a neutral position at heel strike to maximally rotating internally when bearing weight, during toe off, and externally rotating during swing. The knee fully extends at heel strike, flexes about 20° before neutral position during mid stance, and further flexes up to 40° before toeing off. The knee abducts approximately 5° and internally rotates during weight bearing and

abducts and externally rotates during swing to return to its neutral position. The ankle is neutrally positioned at heel strike (approx. 0-10° of plantarflexion), as it progresses to foot flat (approx. 10° dorsiflexion) it quickly plantar flexes to propel the body forward (approx. 20° plantarflexion). The subtalar joint supinates at heel strike and pronates through foot flat to supination at heel off. (Jones & Barker, 1996, pp.301-302; Brunnekeef et al., 2005, Table 3.)

4.2 Gait and the kinetic chain

During gait the different segments of the body that are linked in a kinetic chain respond to an external force that transfers from each division to another adjoining division. It consequently causes an overall response to the whole kinetic chain. The gait cycle incorporates both closed and open kinetic chains, however the closed kinetic chain phases of the gait cycle play a more significant role in establishing movement patterns. (Svoboda et al., 2016.)

An example of this significant role of the kinetic chain, is the importance of lower limb range of motion in multiple joints, and its association in evoking “impaired pain-free knee function” in Individuals with PFPS (Ophey et al., 2023).

Running is considered more of a closed kinetic chain activity as the heel makes contact with the ground and are big determining factors in establishing running movement patterns. Running in turns generates a large amount of ground reaction force. It includes reactions within the frontal chain, the posterior chain, lateral chain, and functional chain that involves the rotational component of the trunk. (Van Den Dries & Capobianco, 2013, p.166.)

4.3 The Running gait

Running has been a major factor in sustaining musculoskeletal injuries. 65% of chronic injuries estimated, in long distance runners, are characterized by distance, intensity, and types of running surfaces. Significant risk factors that especially stem from its unique biomechanics to the influence of fit and use of

footwear, as well as its possible associated training errors. (Lohman et al., 2011.) Therefore, it is important to establish the difference between walking and running as it differentiates biomechanical features of each activity.

What differentiates walking from running within the gait cycle is the absence of double limb support in instances where both feet are at a point take contact with the ground simultaneously, whereas in walking gait, the whole cycle alternates between single and double support (Lohman et al., 2011). Based on these terms, the running gait cycle is also comprised of the two main phases that are known as the stance and swing phase. The stance phase is comprised of an absorption and propulsion state, whereas the swing is separated into pre swing and terminal swing. Specific to the swing phase, an addition of two double float phases (no contact with the ground) occurs at the “end of toe off, and the beginning of initial contact”. (Novacheck, 1998.) This is visualized in Figure 2.

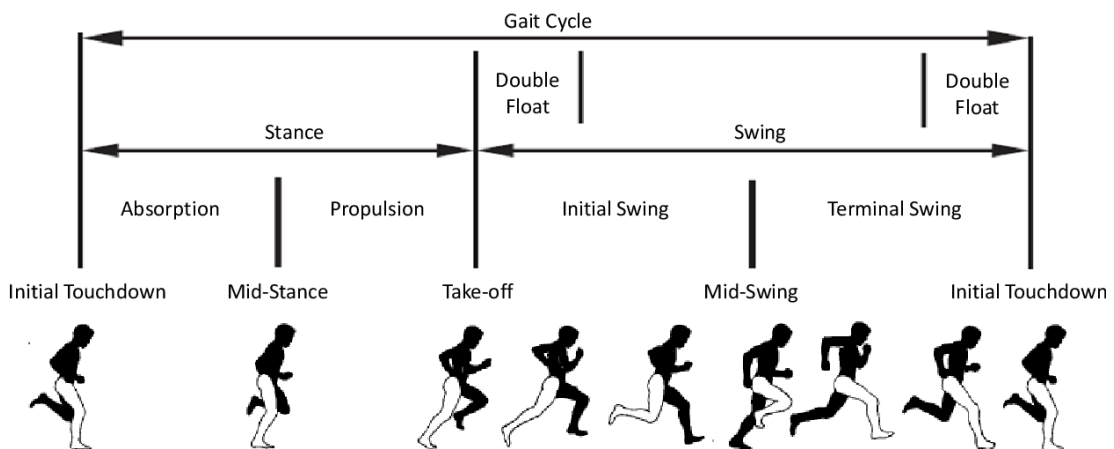


Figure 2. The running gait cycle (Bridgman, 2015).

Biomechanically, during running there is an increase in ground reaction force (GRF), and center of pressure (COP) to approximately 250% of body weight (BW) (Physiopedia, 2023, Running Biomechanics). Additional characteristics of the running gait come from its kinetics as center of gravity (COG) lowers and the body moves further in its wider ranges of motion to accommodate in accordance with the increasing speed and lowered center of mass (COM)

(Kapri et al, 2021). Thus, running is a high load and high stress activity to the lower extremity relative to the force generated.

4.3.1 Running kinematics

While the phases stay alike to walking, the major joints of the lower extremity move along a larger range of motion. Previously stated, running speed correlates to ranges of motion fluctuations during sub phases of the gait cycle. The standard ranges of kinematics in the lower extremity are presented as so. The hips flexes at around 25-30°, during the first foot strike and progresses into 20° extension during toe off. The knees do not ever fully extend during the running gait but progress from flexion of 10° or more and during support phase further into 20-30°, and finally extends to 15-20° of flexion during propulsion. Though ankle movement during running gait can be influenced by different foot strike patterns, during foot strike the ankle plantarflexes to around 5°, or 15-20° of dorsiflexion at the first half of support, until the second half where it plantarflexes approximately 30° prior to toe off. (Hawley, 2000, pp.28-29.)

Despite such literature, according to Orendurff et al. (2018), there is a significant correlation between speed and resultant peak kinetic and peak kinematic variables of the hips, knee, and ankles. Likewise, an increase in gait velocity will increase vertical GRF, step length, cadence and stride length. Additionally, an increase in velocity decreases the percentage of double limb stance in addition to the entirety of stance, whilst percentage of the swing phase increases. As a result, it would decrease the duration of the whole gait cycle. (Liu et al., 2013.) Which is why such temporal measures should be carefully taken into consideration when assessing such gait variables.

4.4 Gait kinetics

According to IMeasureU (2019), the definition of kinetics within biomechanics is the study of force and its influence in movements of body segments and vice versa. Kinetics within gait whether it is walking or running, involves

components such as ground reaction force (GRF), mechanical moments of the lower limb joints along with their powers, as well as kinetic or potential energy. (Lencioni et al., 2019.) A plethora of external forces are directed towards the patellar femoral joint and generates a large portion of total force produced during closed chain activities such as running. The ground reaction force (GRF) is “the force generated between the foot and the ground” following Newton’s third law of motion and is influenced by various factors (Hawley, 2000, p.33). Mechanical moments/ torque refers to the resultant rotation at a joint that occurs through the application of force (Malik & Malik, 2015, p.6), whilst power refers to “the rate at which work is done” (Hamm, 2020). An example of measuring kinetics is information about GRF through data about plantar pressure during the gait cycle of its different phases. (Tao et al., 2012.)

4.5 Spatio-Temporal parameters (TSPs)

Another set of parameters related to gait are referred to as spatiotemporal parameters (TSPs). Spatial referring to distance parameters, and temporal meaning parameters that are related to time. Spatial parameters in gait include step width (distance between heels of each foot), step length (medio-lateral distance between feet in each heel strike), as well as stride length (total length from one heel to the same heel again in the gait cycle). Temporal parameters in gait include walking speed, cadence (steps per minute), time, duration of phases and subphases, as well as step and stride time. (Scataglini et al., 2021.) TSPs are highly important in assessing the foundational basis of gait. The data retrieved from such parameters can be used for screening (e.g. risk assessment), performance measure, monitoring, and normalization of different aspects of gait measurements. (Kirtley, 2006, p.21.)

5 GAIT ANALYSIS IN RUNNERS

A running gait analysis may be utilized as a technique in finding biomechanical faults in runners (Joseph, 2022). Running as a form of physical activity itself places a heightened amount of stress to the lower extremity whether it is from intrinsic or external factors. As the knee functions, it relies on the patella acting as a pulley as previously stated. It undergoes one of the highest amounts of load and compressive forces in the lower extremity during running from 5.6 times of body weight (BW) up to 7.8 times BW during deep squatting. One example of a biomechanical fault associated with PFPS that may contribute to the overload and increased PFJRF, may include discrepancy within the dynamic Q-angle. The Q-angle acts to measure the line of pull from the quadriceps muscle group that may reflect the extent of force directed laterally. The dynamic Q-angle can be measured during functional lower extremity movement analysis. (Loudon, 2016.)

Concurrent studies describe the usability of clinical gait analysis within allied health and assess its present state and future development. Gait analysis is currently used as a measure to identify different walking patterns and capacities to monitor and evaluate ongoing rehabilitation. It also serves to find appropriate and specific treatment as well as indications of a predictive outcome. Mostly used in practice by clinicians is observational analysis, due to its availability, simplicity and low cost. However, Instrumented gait analysis provides further accurate and quantitative data in establishing certain characteristics and patterns of gait. (Hulleck et al., 2022.) It is currently mainly used within research and considered a “Gold standard of gait analysis” according to Hulleck et al., (2022). On the other hand, whilst it produces reliable and accurate data, instrumented gait analysis is considered costly, requires extensive equipment, complex protocols as well as a good system of storing data and conducting analysis. This compels a well-educated and trained team of professionals to operate as well as their preferences. (Hulleck et al., 2022.)

The reliability of observational gait analysis in individuals with lower extremity orthopedic/ musculoskeletal impairment was explored in a study done by Brunnekeef et al, (2005). Observation gait analysis in literature often focuses on neurological, amputee, rheumatoid arthritis, therefore brushing its usability in orthopedic impairments aside causing a resultant lack of literature surrounding it. It is believed the presentations of impairments in orthopedic conditions are less noticeable visually in comparison to movement deficits in neurological conditions, for an example side differences in stroke rehabilitees. This study focused on physiotherapist participants who were experienced, inexperienced, or experts in the field of visual gait analysis by assessing videotaped footage of orthopedic impairments. The same protocols and materials were used by all participants. Results showed that observational gait analysis for orthopedic patients was moderately reliable. Furthermore, higher reliability was present between the three groups of physiotherapists in movements related to the knee before heel strike, trunk movements, and movements regarding arm swing. (Brunnekeef et al., 2005.)

5.1 Methods of Gait analysis

Gait analysis can be divided into both qualitative and quantitative analysis. Of the two divisions, there is a separation of quantitative gait analysis into joint kinematics, kinetics, and TSPs that produce numerical data. (Types of GAIT Analysis ProtoKinetics, 2021). For qualitative analysis/ observational analysis, the idea is to assess gait only through questionnaire-based scales, or observation-based scales. Observation-based scales focus on assessing gait in real time or through video recording. Questionnaire based scales on the other hand, assesses gait using questionnaires that collect data about capacity in performing specific tasks such as walking, or could be used as an evaluative tool to assess quality of life based on the different components of the ICF model. (Moissenet et al., 2015.)

Real time observational gait analysis begins the moment a patient walks in for an appointment. Both sides of the subject are observed from the lateral view,

in addition to the anterior and posterior. For runners, it is important to assess gait under various running conditions other than walking. Formally, the subject should be observed with footwear on, despite obstructing the view of foot mechanics during the weight bearing phases of the gait cycle. (Manske & Davies, 2016.) In a study done by Eggleston et al (2023), a study compared non footwear to footwear and its influence on lower extremity biomechanics. Results indicated that footwear influenced angular ankle joint position for longer than half of the gait cycle. Whereas angular knee joint position for around 20% of the gait cycle. Furthermore, gait velocity increased with shoes, and stance width increased without shoes. Therefore, in practice, it is important to carefully consider barefoot conditions to establish the subject's baseline findings.

The different objective analysis methods for gait are stride analysis, angular kinematic analysis, force plate/foot pressure analysis, as well as electromyography analysis, all of which measure different components of gait (Nordin & Frankel, 2012, p427). These of which produce numerical data that could be compared, as well kept in records.

In stride analysis, the aim is to measure time-distance variables such as the TSPs. Angular kinematic analysis aims to measure angular displacement of joints and measures segmental displacements and velocities. Force plate/ foot pressure analysis measures ground reaction force and the location in which the force is applied at the bottom of the feet, and load distribution along the sole of the foot during stance phase of the gait cycle. Angular kinematic analysis and Force plate/foot pressure analysis methods are often coupled to derive data to calculate kinetic variables of joint movement. Electromyography measures activation of muscle groups to provide data about muscle activation patterns when combined with stride analysis or angular kinematic analysis. (Nordin & Frankel, 2012, pp.427-428.)

Equipment used for objective gait analysis methods may include but not limited to the use of a simple stopwatch, ruler, pen and paper, and can range up to technologically advanced and specific equipment such as smartphones with

built in sensors, wearable sensors, as well as sensing fabrics to collect numerical data (X. Liu et al., 2021).

6 RELATIONSHIP BETWEEN PFPS AND GAIT

Current evidence suggests biomechanical gait discrepancies associated with PFPS are found in 3 categories: kinematic parameters, TSPs, and kinetic parameters. Each subdivision of the kinetic chain displayed specific characteristics, and evidence was divided in such a way.

6.1 The pelvis and hip

According to systematic reviews and meta-analyses conducted, it has been found that individuals with ongoing PFPS are shown to have a reduction in range of motion of the pelvis along the frontal plane while running (Haghighat et al., 2021). On the contrary, individuals with ongoing PFPS displayed the presence of a contralateral pelvic drop (Bazett-Jones et al., 2022b; Bramah et al., 2018; Neal et al., 2016; Nourbakhsh et al., 2018; Vora et al., 2017). In relations to the hip region, PFPS runners were characterized to have increased peak hip adduction angles whilst running (Xie et al., 2022; Neal et al., 2016; Nourbakhsh et al., 2018; Vora et al., 2017; Haghighat et al., 2021). Accompanied by this is an increase in peak hip internal rotation (Neal et al., 2016; Bazett-Jones et al., 2022b; Nourbakhsh et al., 2018; Vora et al., 2017), and peak hip flexion angles (Bazett-Jones et al., 2022b; Nourbakhsh et al., 2018).

6.2 The knee

Amongst women with PFPS, range of motion of the knees increased along the frontal plane but decreased along the sagittal plane whilst running (Haghighat et al., 2021). Additionally, individuals with ongoing PFPS displayed decreased peak knee flexion (Bazett-Jones et al., 2022b; Haghighat et al., 2021.) with

faster walking speeds (Arazpour et al., 2018). Individuals with PFPS also displayed an increase of knee extension angle during heel strike (Bramah et al., 2018). However, found in PFPS subjects, was a decrease in knee extensor moments (Arazpour et al., 2018; Nourbakhsh et al., 2018; Bazett-Jones et al., 2022b; Haghghat et al., 2021). Across multiple reviews, it was also identified that affected individuals also displayed an increase in peak knee adduction angles during midstance of the gait cycle (Bramah et al., 2018; Arazpour et al., 2018; Vora et al., 2017; Yalfani et al., 2023). Knee abductor moment peaks also increased during loading phases (Arazpour et al., 2018). Finally, individuals with PFPS demonstrated an increase in knee external rotation during the gait cycle (Arazpour et al., 2018).

6.3 The ankle and foot

Ankle and foot related discrepancies lacked enough available and quality research articles, but identified discrepancies related to both kinetic and kinematic variables. Of the available reviews, it was found that individuals with ongoing PFPS, showed a wider distribution of plantar pressure in the medial and central hindfoot during heel strike, medial-lateral forefoot in midstance, and lateral forefoot during propulsion (Willwacher et al., 2022; Arazpour et al., 2018). A study conducted by Bramah et al, (2018) indicated that PFPS individuals displayed an increase of ankle dorsiflexion during heel strike. Most importantly, PFPS is associated with an increase in peak rear foot eversion during heel strike (Bazett-Jones et al., 2022b; Arazpour et al, 2018; Nourbakhsh et al., 2018; Martinelli et al., 2022).

6.4 TSPs, Kinetics and other observations

It was mainly found that individuals with PFPS had decreased step length in faster walking speeds (Arazpour et al., 2018; Bazett-Jones et al., 2022b; Nourbakhsh et al., 2018), a decrease in cadence during walking and stair climbing, as well as a decrease in speed and velocity during the swing phase (Arazpour et al., 2018). Furthermore, PFPS also kinetically displayed a reduction of GRF

during walking (Arazpour et al., 2018). More specifically, a decrease in braking impulse in GRF and increased contact time with the ground (Willwacher et al., 2022). Other factors noted with active PFPS was the forward lean positioning of the trunk during running from a laboratory study conducted by Bramah et al, (2018).

6.5 Uncertainty and limitations within literature

A systematic literature review and meta-analysis conducted by Willwacher et al (2022) about biomechanical risk factors in overuse running injuries, suggested multiple considerations for uncertainty and limitations of studies exploring biomechanical risk factors in overuse running injuries. One suggestion states the individual biomechanical variance between individuals sampled in included studies, minimized the ability to generalize findings. One example is the biomechanical variances between male and female runners, as studies do not accumulate generalizable observations based on heterogenous samples, due to such individual factors. Additionally, studies also fail to consider the differentiation between recreational and competitive runners as such factors influence physical activity level differences in risk factors associated with attaining such overuse running injuries. Ultimately, literature surrounding biomechanical risk factors, as well as the combination of biomechanical risk factors and other factors are insufficient. This suggests the multifactorial quality of such overuse running injuries should consider internal and external forces in synthesizing a curated profile. Willwacher et al., (2022) proposed considering individual factors as previously stated along with factors such as training and lifestyle to create a comprehensive profile on the occurrence of overuse injuries such as PFPS.

PFJRF on the theory of load reduction and compensation suggested by Arazpour et al., (2018), as well as Willwacher et al., (2022), Yalfani et al., (2023), and Haghghat et al., (2021) all touch on the topic of possible reasons behind presented observations of associated characteristic in gait patterns. For an example, the literature review conducted by Arazpour et al., (2018), suggested

such occurrences in TSP variables may be a product of quadricep muscle activation patterns of which contribute to the loading of the PFJ, and its possible influences on pain. Similarly, Haghghat et al., (2021) suggested possible explanations to the findings, is based on the theory of ridged stabilization techniques to reduce the impact of the PFJRF. However, the main limitation of the prevalence of such characteristics may be the inability to establish the cause-effect relationship of PFPS and observed gait characteristics from literature according to Yalfani et al., (2023). As suggested by Willwacher et al., (2022), factors of load reduction may be addressed through considering footwear, taking preventative measures, as well as a possible indication for gait-retraining during rehabilitation.

According to Bazett-Jones et al (2022b) systematic review and meta-analysis, the highest level of evidence of gait characteristics in PFPS ranges from low to moderate evidence. Across multiple systematic suggested consensus surrounding the evidence on such recorded characteristics in studies is found to be at most of moderate evidence. Moreso, it was found quality of evidence was typically described to be limited, inconsistent, or conflicting across review articles.

7 METHODOLOGY

A practice-based method was selected to achieve the objective of this exploration as it produces a product that is distributed to a client. Ultimately the goal of producing a product, the expected outcome is to increase competency and knowledge in orthopedic Gait analysis for physiotherapy students in an applied manner. With the practice-based method, a comprehensive/ integrative literature search and review was conducted to acquire both theoretical and evidence-based practice to be implemented into the guidebook in establishing an intuitive framework of addressing Gait analysis. The completed guidebook was piloted to collect feedback as a measure of its effectiveness and its

indications for future developments. The process of writing this thesis report was approximately a yearlong project and the timeline is outlined in Table 1 below.

Table 1: Thesis project timeline and stages of implementation

Thesis project timeline	Phases
March 2024	Gathering literature, writing theoretical background
April 2024	Writing theoretical background, Planning of guidebook
May 2024	Planning of guidebook
June 2024	Drafting gait analysis form/ questionnaire
July 2024	Literature search, data collection, development of themes
August 2024	Drafting and creating guidebook
September 2024	Creating guidebook
October 2024	Distribution of guidebook, creating feedback form, collecting feedback
November 2024	Finalizing thesis report (process, discussion), presentation

7.1.1 Reliability: Comprehensive/ integrative literature search

Reliability and quality of this thesis product relies on a well comprised and communicated literature search process and thesis product. Therefore, a well conducted comprehensive literature search must be implemented as a protocol to attain adequate and reliable literature to include in the thesis product.

A comprehensive/ integrative literature review was chosen to gather the most up to date literature of research, books, and other forms of literature to produce new insights, to identify, and to evaluate current state of a research topic (Paré

& Kitsiou, 2017). An integrative literature review is characterized by its ability to widen and “diversifies knowledge on a topic by integrating knowledge from across the communities of practice that study it” as stated by Cronin and George (2020). This type of literature review, like others, is composed of a data search phase that obtains all relevant, extensive, and balanced knowledge in a topic, but as well from other similar disciplines. Therefore, data collected are from a range of research methodologies, as well are composed of empirical and theoretical knowledge. This is then followed by a phase dedicated to thematic synthesis of the included knowledge within the scope of the study. During this phase, shared findings, juxtaposing findings are allocated into themes to answer the relevant research question, to produce a refined conclusion. (Cronin and George., 2020.)

To gather multidisciplinary data and knowledge about gait analysis, a specific and refined research question must be defined. This literature search aims to answer the following research question regarding assessment methodology in the place of an intervention, therefore one question synthesized covering multiple disciplines and the theoretical framework is: What are the associated gait characteristics in runners diagnosed with PFPS? Furthermore, the scope of the thesis focuses on gait analysis and PFPS in physiotherapy therefore the main research question is: To what extent can gait analysis be considered a reliable assessment method for runners with PFPS?

To answer the multidisciplinary research question, inclusion and exclusion criteria are established. For an article to be included, (1) it must be no older than 10 years. (2) It must include the term ‘gait’, ‘running’, or ‘walking’. (3) It must include the term ‘Patellofemoral pain syndrome’, or ‘overuse’/‘overload knee injury’. Furthermore, (4) the content of the articles must discuss about biomechanics such as temporal-spatial parameters, kinetics, or kinematics (5) and written in English.

The exclusion criteria reflect the opposite of the inclusion criteria. They are as follows, (1) articles are older than 10 years, (2) they exclude the term ‘gait’, ‘running’, or ‘walking’, (3) they exclude the term ‘patellofemoral pain syndrome’, or ‘overuse knee injury’/‘overload knee injury’, (4) the article does not

discuss about biomechanics involving temporal-spatial parameters, kinetics, or kinematics, (5) it is written in another language other than English.

Articles screened are collected from indexed databases PubMed, PubMed Central, Science direct, Springer Link via the search engine Google Scholar and PubMed search which are depicted in Table 2.

Table 2: Literature search and inclusion process of research articles

Data search engines	Search words	Excluded articles and criteria	Included articles
PubMed (15)	(Gait analysis OR walking analysis OR running analysis*) AND (Patellofemoral pain syndrome* OR PFPS*) AND (Athletes* OR Runners*)	(7) excluded based on heading	1
		(6) excluded based on abstract	
		(1) excluded based on content	
Google Scholar (43)	(Gait analysis OR walking analysis OR running analysis*) AND (Patellofemoral pain syndrome* OR PFPS*) AND (Athletes* OR Runners*)	(4) excluded based on heading	10
		(20) excluded based on abstract	
		(6) based on content	

A supplementary manual search is also conducted to collect theoretical knowledge to include in the guidebook. Due to the broad realm of literature,

search and selection is only based on distinct context and excludes any specific exclusion or inclusion criteria to consider sub-themes. Likewise, it seeks to answer the main research question, by bridging different relevant disciplines as well as theory to empirical evidence from research articles, as stated previously. This mainly provides theory and additional forms of knowledge for the guidebook to be cohesive and provide relevant background and foundational knowledge to coincide with evidence-based data. All theoretical and empirical literature used in the guidebook are depicted in Appendix 1.

Upon collection of research articles through the inclusion process, themes relevant to the main research question were derived and categorized depicted in Table 3, which is used in framing the sub-themes to the main topic at hand.

Table 3: Thematic synthesis of included data

Sub-themes	Contents of sub-themes
Patellofemoral Pain Syndrome	PFPS definition
	Prevalence
	Etiology & risk factors
	Anatomy and biomechanics of Patellofemoral joint
	Differential diagnosis and physiotherapeutic interventions
Gait	Gait cycle
	Running gait
	Observational gait analysis
	Instrumented gait analysis
Observational gait analysis in orthopedics	What to observe
	How to observe
Evidence based observations of Gait in PFPS	Associated gait characteristics in individuals diagnosed with PFPS
Gait observations	Interpretation of evidence-based observations
Instrumented gait analysis	Stride analysis

	Angular kinematic analysis
	Force plate/ foot pressure analysis
	Electromyography
Advantages and disadvantages of gait analysis	Limitations
	Utilization

7.1.2 Guidebook

In comparison to Manuals and handbooks, Guidebooks are concise materials which offer guidance and assistance in a specific context or activity wise. They are shorter in length and often offer necessary information that is not extensive or overly detailed to fulfil this goal. Guidebooks in comparison to manuals and handbooks are more visually appealing and intuitive to use for simple navigation. (Bhayani, 2024.) Ultimately, a guidebook was chosen as the implementation format for this process because “Guides provide summaries, tips, recommendations, and suggestions to facilitate user understanding and decision-making.” According to Bhayani (2024). For physiotherapy students, the goal is to make information search and guidance in implementation of gait analysis accessible, whilst at the same time facilitating their own critical thinking and clinical reasoning process. Ultimately, this may develop knowledge competency on the topic of assessment through gait analysis.

Based on the thematic division of the themes in Table 3, a guidebook was created to compile all included knowledge and data together to fulfil its goal as a guidebook. The guidebook was designed as a downloadable pdf format that is created on the platform Canva. It was available for students to save and keep as support materials. It comprises a total of 17 pages and outlines the 7 sub-themes established in the literature review phase. Please refer to Table 3 to understand the structure and organization of the final product. Additionally, a visual gait analysis form is formatted similarly to the form included in a study done by Brunnekeef (2005) and implements evidence-based observations translated and transformed into a usable table to support the application of

observational gait analysis. This implemented form is depicted in Appendix 2. Furthermore, integrated guidance questions are implemented in the content of the guidebook to challenge the reader's own evaluation of gait analysis through the guidance of evidence-based practice. Images and diagrams were implemented throughout the guidebook to visualize and simplify descriptions of gait analysis making the guidebook comprehensible, concise, and visually communicative.

The final guidebook was distributed via email to all current physiotherapy students in SAMK along with its instructions on participation. After the distribution of the completed guidebook, a feedback questionnaire was instructed to be filled in after reading through the guidebook.

7.2 Feedback

Feedback was collected as a measure of effectiveness of the guidebook from the student participants. Specifically, to evaluate the value of the guidebook and to assess their own learning process upon reading it. Additionally, it served to collect developmental ideas and suggestions for improvement if had the opportunity to develop and undergo multiple rounds of piloting. The content of the feedback form focused on the evaluation of its content, students' outcomes, its usability, as well as overall quality of the guidebook. Measurements were done on a numerical scale from 1-5 or 1-10, as well as open-ended questions. A sample of the feedback form is depicted in Appendix 3.

7.3 Ethical considerations

According to ethical guidelines of writing a thesis established by the Rector's Conference of Finnish Universities of Applied Sciences Arene, all matters for possible ethical considerations are checked off on the behalf of the author for the thesis report. In addition to the ethical guidelines, the author has identified additional considerations for the finished guidebook product.

The finished guidebook was not published in open access but used as a part of the thesis writing process during interpretation. A statement was put out to participants of the pilot in statement to address inappropriate distribution of product for the behalf of the participants.

The content of the guidebook was meant to be taken with a grain of salt, and not used as official guidelines nor formal publication to be referenced therefore no copyright legislation is applied to the body of work. Similarly, the finalized guidebook distributed was not to be interpreted in its improved form as its own evidence. Respectively, the process did not involve a fully conducted research process such as systematic literature reviews, nor did the process include a development and re-piloting stage. Therefore, it was not considered as its own empirical evidence or its own reference for external validation. The author was not responsible for inappropriate use nor the misinterpretation of knowledge from this guidebook by participants.

Feedback collected from participants in the piloting of the guidebooks does not include personal data. Feedback was summarized based on the collective responses. Participation in feedback was non-binding, and thus participants were allowed to withdraw at any stage. Consent in participation was attained through voluntary informing. After collection and interpretation of the feedback results, data was appropriately removed and eliminated from data storage to address data security issues after the thesis report is published. The author stated there is no conflict of interest in the process of creating the guidebook. Furthermore, author promised transparency of interpreting literature as they are.

Communication of these ethical considerations to participants was done through email during the piloting phase and receiving a response confirmation of having read the terms.

8 CONCLUSION

Ongoing PFPS is suggested to be associated with factors relating to the over-use/ load of the PFJ or with certain biomechanical faults such as the dynamic Q-angle. Such factors are identified through movement assessment, one example by assessing gait. It is suggested these associated characteristics of PFPS can be based off the principle of PFJRF and factors affecting it. At its highest level, between systematic literature reviews and meta-analyses, there is low to moderate evidence of evident gait discrepancies associated with PFPS. Repetitive kinematic features identified through studies included the presence of contra-lateral pelvic drop, larger hip flexion angles, an increase of rear foot eversion, the presence of increased internal rotation at the hip, and increased peak knee adduction angles. Repetitive kinetic features identified throughout studies included the presence of decreased peak knee extension and flexion moments. Repetitive TSPs features across evidence-based literature identified there to be a decrease in step length in individuals with PFPS.

However, there is a lack of understanding of the cause-and-effect of such biomechanical discrepancies as theoretical literature did not fully reflect current evidence-based knowledge. Evaluating the reliability and validity of observational/visual gait analysis within orthopedics presented its challenges. This is due to a critical lack of up-to-date literature, and inconclusive evidence within this specific topic. Therefore, validity and reliability of observational gait analysis utilized for patients with ongoing PFPS was not fully established.

The procurement of theoretical and article-based knowledge included in the guidebook, based on feedback, yielded a response of high value in observational gait analysis competency, and served to challenge and guide an individual's clinical reasoning skills in approaching conditions like PFPS as a physiotherapist.

9 DISCUSSION

Literature about PFPS and gait analyses as a topic together in the state of research is currently highly limited. PFPS and its broad nature, lacks consensus whether its assessment methods are clinically reliable. There is a need to establish reliable and valid assessment tools and methods to help dictate the direction of knee rehabilitation.

As previously stated, all accumulated articles implemented produced only a handful of empirical literature out of the 4 established databases where literature search was conducted. Therefore, a lot of nuances were kept in mind when creating the guidebook. The decision to use google scholar in the end as the main search engine, was due to its ability to gather scholarly articles through its extensive network of indexed databases across multiple disciplines. This made the search process as less strenuous as possible, additionally, well fitting for the literature review methodology used. Although there was an overlap of observations in individuals with PFPS across all literature reviews, the guidebook still lacked literary consensus bridging between theoretical knowledge of sub-topics and empirical evidence, especially those that are accumulated through a manual search under undefined search terms during the process. In finality, it reduced its literary reliability by the end of the pilot.

Additionally, to this aspect of the literature search and implementation, the topic of PFPS and gait combined in accumulated articles, identified a common limitation to the topic at hand and posed a difficult question, “Are these gait characteristics associated with PFPS, a product of compensatory mechanisms, or do they present the nature and mechanism of the injury?”. The area of uncertainty in the aspect of the ‘why?’ is due to PFPS’s multifactorial etiological nature. As the results of the literature search established this, research articles highlighted the need to conduct a comprehensive assessment of PFPS, rather than focusing only on the biomechanics of the injury. Ultimately, observational gait analysis is not a sufficient method to assess PFPS as it does not reveal all relevant and significant details in an injury, such as muscular

imbalance suggested by Maffeton (2020), or knowledge of the individual's physical activity levels that may impact injury occurrence as suggested by Willwacher et al., (2022). Based on current practice guidelines in assessment of PFPS by Willy et al., (2019), guidelines suggest examination should utilize physical activity limitations or self-report questionnaires, to examine PFPS and use them as outcome measures. The questionnaires included in the lineup are the Anterior Knee Pain Scale (AKPS), Visual Analogue scale (VAS), Numerical Pain Rating Scale (NPRS), Patellofemoral pain and osteoarthritis subscale of the Knee injury and Osteoarthritis outcome score (KOOS-PF), or the Pierzynowski Questionnaire (EPQ) according to Willy et al., (2019). Alongside this assessment method, implementation of clinical or field tests to assess pain and lower limb movement coordination, favorably different variations of squatting, to address pain, disability, and function.

Another limitation in the use of gait analysis as an assessment tool with runners is the variability between individuals. A runner who may have noticeable discrepancies in their step, may not have symptoms nor reproduction of symptoms in a chronic ongoing running injury or vice versa. This creates uncertainty if gait discrepancies in runners are present or visible and relevant in injury management. As suggested by Maffeton (2020), gait analysis under controlled environment may also influence movement behavior of the individual overall, decreasing the overall reliability as a standalone assessment method. Therefore, the multifactorial nature of PFPS presents an additional challenging question, "what other factors influence gait behavior?".

To identify the advantages and pitfalls of the gait analysis guidebook, feedback was collected about the quality of implementation and effectiveness of the guidebook. To summarize the feedback, four themes were identified and illustrated in Table 4.

Table 4: Results of participant feedback

Theme	Scale	Overall feedback
Content (relevancy of content)	No/yes	Yes, it was convenient to read as it included necessary knowledge to have as a physiotherapist. Yes, I only knew some of the knowledge previously.
Outcome (evaluation of own competence before and after reading guidebook)	1-5	Before Mean value: 2
		After Mean value: 3
Usability	No/yes	Yes
Quality	1-10 and open-ended answers	Mean value: 9

Open feedback was also collected about the quality description of the guidebook, as well to garner developmental ideas. Results showed that the overall quality of the guidebook was on average rated 9 on a numerical scale from 1-10. Open feedback described the guidebook as logically structured and well organized. The knowledge compiled for the guidebook was necessary, useful, thorough, as well as concise whilst being evidence based. Furthermore, the quality of the guidebook was described as good and comprehensible, meaning there was an adequate amount of information, easy to read and straightforward. Participants also suggested improvements to be made to the design of the guidebook, which included the use of more diagrams, a table of contents, as well as shortening some amounts of text. Participants suggested the implementation of applicable case studies to further activate the reader's own clinical reasoning. Feedback also suggested implementing a section dedicated to guidance in rehabilitation planning based on the interpreted findings from the

gait analysis. This further prioritizes the need for gait assessment in PFPS to be interconnected with other assessment methodologies as well as the implementation of rehabilitation. As suggested, gait analysis cannot be a topic of discussion unless other assessment methodologies are considered and the topic of implementation of rehabilitation such as gait retraining are discussed upon, furthermore emphasizing conducting a comprehensive assessment.

The overall aim and objective of the thesis was achieved, as results of the exploration of using Gait analysis in addressing PFPS concluded the lack of literary consensus but provided multiple insights and considerations to the characteristics of PFPS. The production of a guidebook combined all relevant perspectives of Gait analysis by applying PFPS guided participants in the process of clinical reasoning, and critical thinking. The role of the physiotherapist is to conduct a comprehensive, concise, and accurate assessment of PFPS of which may include a gait analysis of the subjects walking and running. The physiotherapist applies their evidence-based expertise in injury management, to identify significant factors of pain influence and select suitable interventions for the individual.

During the reporting process the author faced difficulties through a handful of nuances in the topic regarding Gait analysis. One example was the interconnectedness of Gait analysis and Gait rehabilitation, that provided more literature to include but, faced conflict in differentiating assessment methodology from the implementation of rehabilitation as they are heavily interconnected. Additionally, the literature search process proved to be extensive with a manual search as the need to ponder relevant sub-themes and identify suitable and relevant literature to include. The process developed and constantly improved in later stages, where pitfalls were identified, and methodology was modified accordingly. The author feels this further facilitated their ability to critically evaluate and implement problem solving and opened the world of multiple disciplines and sub disciplines within the topic of biomechanics. Production of the guidebook was a new challenge for the author as it was created with their own creative input through design and format. The feedback of the product indicated its success in its accessibility and comprehensibility towards the

right target group, although the author believes the product has a long way to go to improve its overall efficacy.

A deeper understanding of biomechanics as a competency is something the author sought after and valued in their professional development during the thesis reporting process. Especially, how much base understanding of it is needed to interpret and comprehend results of research articles. The implementation of the guidebook was a success, despite the limited quantity of quality literature. In addition, the author has identified the state of research in the topic to be constantly developing as more empirical evidence is sought after to provide PFPS 's complex background more clarity. The process challenged the author to critically think about nuance and fairly evaluate the quality of evidence. It implemented usable and comprehensible material for amateur physiotherapists in the development of knowledge competency especially around biomechanics and human movement, as it was a relatively new knowledge domain for the author.

9.1 Development and future direction of thesis project

The author believes the main pitfall of the reporting process was the lack of re-piloting stages of the guidebook. This considers the implementation of action research to its full extent. Specifically, by broadening the topic of gait analysis to include the implementation of gait re-education. The definition of action research is to enact in collaborative involvement to apply action-based learning and science to improve practice or conditions amongst multiple disciplines and their environments, such as those involved in health care (Casey et al., 2021). In this case, the improvement of gait assessment and re-training protocols in knee related pathologies between practitioners. Action research is characterized by its phases of action, and reflective phases, where both are cyclical in respective to each other (Casey et al., 2021).

The main aspect considered in the implementation of the action research methodology is its emphasis on active external collaboration between

practitioners and patients. This means the involvement of collaborators in the inquiry, research, and participation during the process. (Casey et al., 2021.) Reflective of this thesis report, involvement of external collaborators such as the physiotherapy students would express what is in need and necessary to cover the topic of gait analysis in individuals with PFPS. Furthermore, this could be conducted by reflecting on their own professional state of development and base competency, as well as providing feedback on the early stages of the guidebook prior to the first piloting phase. This provides added value to the physiotherapy community and insights on the finished product.

In addition, by implementing action research to its full extent through its cyclic feature, it facilitates constant development of the production process and content from the multiple stages of piloting. In comparison to one, it could potentially yield improvements in the efficacy of the guidebook by overall improving the quality of the product.

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APPENDIX 1

Search method	Title	Author
Comprehensive literature search	Running-Related Biomechanical Risk Factors for Overuse Injuries in Distance Runners: A Systematic Review Considering Injury Specificity and the Potentials for Future Research	Willwacher et al., (2022)
Comprehensive literature search	Dynamic foot function as a risk factor for lower limb overuse injury: a systematic review	Dowling et al., (2014)
Comprehensive literature search	The effect of kinetic factors of dynamic knee valgus on patellofemoral pain syndrome: A systematic review and meta-analysis	Yalfani et al., (2023)
Comprehensive literature search	Patellofemoral pain syndrome and its effect on the walking of affected subjects: Update review	Nourbakhsh et al., (2018)
Comprehensive literature search	Patellofemoral pain syndrome in female athletes: a review of diagnoses, etiology and treatment options	Vora et al., (2017)

Comprehensive literature search	Does the foot and ankle alignment impact the patellofemoral pain syndrome? A systematic review and meta-analysis	Martinelli et al., (2022)
Comprehensive literature search	The Relationship between Patellofemoral Pain Syndrome and Hip Biomechanics: A Systematic Review with Meta-Analysis	Xie et al., (2022)
Comprehensive literature search	Runners with patellofemoral pain have altered biomechanics which targeted interventions can modify: a systematic review and meta-analysis	Neal et al., (2016)
Comprehensive literature search	Kinematic and kinetic gait characteristics in people with patellofemoral pain: a systematic review and meta-analysis	Bazett-Jones et al., (2023)
Comprehensive literature search	The effect of patellofemoral pain syndrome on gait parameters: a literature review	Arazpour et al., (2016)
Comprehensive literature search	The effect of patellofemoral pain syndrome on patellofemoral joint kinematics under	Yang et al., (2020)

	upright weight-bearing conditions.	
Supplementary search	Management of patellofemoral pain Syndrome	Dixit, (2007)
Supplementary search	Gender differences in the incidence and prevalence of patellofemoral pain syndrome	Boling et al., (2010)
Supplementary search	Patellofemoral Pain Syndrome: Proximal, Distal, and Local Factors	Davis & Powers, (2010)
Supplementary search	Patellofemoral Pain Syndrome.	DY. Gaitonde, (2019)
Supplementary search	Biomechanics and pathomechanics of the Patellofemoral joint	Loudon, (2016)
Supplementary search	Human kinematic, kinetic and EMG data during different walking and stair ascending and descending tasks.	Lencioni et al, (2019)
Supplementary search	Gait phase varies over velocities.	Liu et al, (2013)
Supplementary search	The pros and cons of Video GAIT analysis.	Maffetone, (2020)
Supplementary search	EXAMINATION OF THE PATELLOFEMORAL JOINT.	Manske et al, (2016)
Supplementary search	Qualitative and quantitative methods of assessing gait disorders.	Moissenet et al, (2015)

Supplementary search	Basic biomechanics of the musculoskeletal system.	Nordin, M., & Frankel, (2012)
Supplementary search	A little bit faster: Lower extremity joint kinematics and kinetics as recreational runners achieve faster speeds.	Orendurff et al, (2018)
Supplementary search	Prevention and treatment of injuries to runners.	Otoole., n.d., prevention
Supplementary search	Gait disorders in adults and the elderly.	Pirker, W., & Katzenschlager, R., (2016)
Supplementary search	Measuring spatiotemporal parameters on treadmill walking using wearable inertial system	Scataglini et al., (2021)
Supplementary search	Update of risk factors, diagnosis, and management of patellofemoral pain.	Sisk, D., & Fredericson, M., (2019)
Supplementary search	Sports Biomechanics	IMeasureU., (2019)
Supplementary search	Patellofemoral pain	Willy et al., (2019)

APPENDIX 2

	Item and question	Side	Early stance	Mid stance	Late stance	Early swing	Late swing
Trunk	1 Is there a forward lean?				Yes/No		
Pelvis	2 Is a contralateral pelvic tilt present?	Left		Yes/No			
		Right		Yes/No			
Hip	3 Is external rotation reduced?	Left		Yes/No			
		Right		Yes/No			
	4 Is extension reduced?	Left			Yes/No		
		Right			Yes/No		
Knee	5 Is extension reduced?	Left					Yes/No
		Right					Yes/No
	6 Is flexion reduced?	Left	Yes/No				
		Right	Yes/No				
	7 Is there an increase in valgus?	Left		Yes/No			
		Right		Yes/No			
Ankle	8 Is there an increase in dorsiflexion?	Left					Yes/No
		Right					Yes/No
	9 Is there an increase in eversion?	Left					Yes/No
		Right					Yes/No
General	10 Is swing phase velocity decreased?						Yes/No
	11 Is step length shortened?	Left					Yes/No
		Right					Yes/No

APPENDIX 3

24/10/2024, 15:07

Gait analysis of PFPS in runners Guidebook for physiotherapy students

Gait analysis of PFPS in runners Guidebook for physiotherapy students

Purpose of this feedback form is to gather opinions and insights of entry level physiotherapists/ physiotherapy students on using gait analysis to address musculoskeletal issues by applying it to a specific orthopaedic case; Patellofemoral Pain syndrome. The results from this form, will be used as a part of the discussion in my thesis about its usefulness and its implementation. Consent in participation is provided by answering this form. Personal data will not be used in the thesis and answers are anonymous.

1. How confident were you in assessing PFPS or conducting observational gait analysis prior to reading this guidebook.

Mark only one oval.

1	2	3	4	5		
No c	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Confident

2. Did you learn anything new from the guidebook?

Mark only one oval.

- No, I have known about the knowledge provided in the guidebook previously.
- No, the guidebook was too extensive or unintuitive for me to learn anything new.
- Yes, since I only knew some of the knowledge previously.
- Yes, a lot/ majority of the information was completely new to me.
- Other: _____

24/10/2024, 15:07

Gait analysis of PFPS in runners Guidebook for physiotherapy students

3. Was the guidebook useful for your development as a physiotherapist/ physiotherapy student?

Mark only one oval.

- No, there are plenty of other accessible material available for me to utilize as a physiotherapist.
- No, the material was unsuitable/ hard to understand for my competency level.
- Yes, it was created in a way that supported my base knowledge in order to deepen it.
- Yes, it was convenient to read as it included necessary knowledge to have as a physiotherapist.
- Other: _____

4. How confident are you in your knowledge about PFPS and gait analysis now after reading the guidebook?

Mark only one oval.

1 2 3 4 5

Not Confident

5. How would you describe the quality of this guidebook? E.g. comprehensiveness, cohesiveness, organisation etc.

6. Is this guidebook useful for you?

Mark only one oval.

- Yes
- No

24/10/2024, 15:07

Gait analysis of PFPS in runners Guidebook for physiotherapy students

7. What would your overall rating from 0-10 would you give this guidebook?

Mark only one oval.

0	1	2	3	4	5	6	7	8	9	10
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. Developmental ideas?

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