Investigation of Differences in Phasic Patterns during a Multicyclic Fatiguing Task

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Attestation of Authorship

I hereby declare that this submission is my work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

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Abstract

This research examined the phasic differences of the lower extremities for a repetitive lifting task using two relative phase techniques, Discrete Relative Phase and Continuous Relative Phase. Both were calculated using the knee and hip angular positions along with their angular velocities in the sagittal plane. Further investigation was carried out using Vector Coding and Principal Component Analysis of the knee and hip angular positions.

Discrete relative phase displayed information of the coupling relationship between the two joints when the distal joint was assessed relative to the proximal joint. The results showed that up to and including the 4^{th} lift the coupling angle of the participants executed an ideal lifting posture where the hip extension leads the knee extension for the entire lifting cycle. For lifts 5 to 21, the participants displayed a distinct phasic difference. From approximately 50% to 100% of the remaining lifting cycle, the knee extension leads the hip extension for the remainder of the cycle.

Continuous relative phase analysis used the angular positions and velocities, which was performed using the raw values or normalizing (+/-1) the raw values. It was found that in normalizing the raw values, temporal information was lost compared to using the raw values. The analysis of raw values showed information consistent with the discrete relative phase analysis, but the continuous relative phase is considered as a higher-order interpretation due to the addition of assessing both angular position and velocity of the two joints of interest. The results from continuous relative phase analysis showed that participants performed what could be referred to as an ideal lifting posture from lift 1, up to and including lift 4, where the hip extension leads the knee extension for the entire lifting cycle. From lifts 5 to 21, continuous relative phase displayed a phasic shift from approximately 50% of the lifting cycle to 100%. The knee extension would then lead the hip extension during the lifting cycle.

Vector coding procedure was used to compute relative phase plots of both the knee and hip joint angular positions. Vector coding procedure displayed unsatisfactory results relating to the assessment of fatigue, due to the results outputting the direction and magnitudes of frame-to-frame vectors, and therefore, valuable temporal information for the entire cycle is lost.

The Principal Component Analysis used the correlation matrix, which produced similar results to discrete relative phase and continuous relative phase. A comprehensive prediction can be made about the two principal-components, which makes up approximately 85% of the variation of the participant's knee and hip angular positions across the 21 lifting cycles. Although the results for one participant yield tangible outcomes, further analysis will be required when applying principal component analysis to several participants and would likely include cluster analysis of the results.

In summary, both relative phase methods yielded the best results for the interpretation of differences in phasic patterns relating to fatigue in multicyclic behaviour. Continuous relative phase provides a higher-order analysis of the results, which provided both continuous spatial and temporal information relating to the two joints of interest.

Acknowledgements

First, and most of all, I would like to thank my primary supervisor Dr Jeff Kilby from the School of Engineering, Computer and Mathematical Sciences at Auckland University of Technology, for his knowledge, guidance, patience and understanding throughout this research. This would not have been possible without your help. Secondly, I would like to thank my secondary supervisor Professor Mark Boocock from the School of Physiotherapy at Auckland University of Technology, again, for his knowledge, guidance, patience and understanding throughout this research which has been invaluable.

Lastly but certainly not least, I would like to thank my parents, who have always encouraged me to reach my full potential and provided me with the support to do that. I hope that in return, the place I have created for you is a place of calm and order, which you both may enjoy for many years to come.

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List of Abbreviations

CRP	Continuous Relative Phase
DOF	Degrees of Freedom
DRP	Discrete Relative Phase
GCS	Global Coordinate System
LCS	Local Coordinate System
PC	Principal Components
PCA	Principal Component Analysis
RMS	Root-Mean-Square

Chapter 1
Introduction

1.1 Background

The biomechanics of humans, along with all other animals possess movements with a high degree of coordination among the system's many parts. These movement patterns belong to both space and time or spatiotemporal exist from which components related to the whole or part of the system is an area of interest. These synergic concepts provided a basis for understanding coordination in biological systems in the early to middle 1980s [1], that originated in studies of rhythmic tasks in humans [2, 3]. The main feature of these earlier dynamical accounts of movement is that they use several assumptions during mathematical modelling [1]. This dynamical systems modelling has led the way for the analysis of inter-joint or inter-limb coordination and variability [4, 5]. There has since been a vast amount of technological advancements including the processing and computational abilities of computers, wireless information exchange, camera and video capabilities to name but a few. These technological advancements have enabled researchers to have a significantly more accurate and efficient way of investigating their research questions relating to biomechanical data. Using these technological advancements has allowed a much deeper understanding of the coordination among the systems of human many joints/parts with the use of dynamical systems modelling.

1.2 Literature Review

A literature review has been carried out for the four techniques within this thesis; they are:

1. Discrete Relative Phase.
2. Continuous Relative Phase.
3. Vector Coding.
4. Principal Component Analysis.

Discrete Relative Phase or Point Relative Phase was first developed by Haken and colleagues [1] who used it for assessing the point in which their hand oscillations experiment transitioned from in-phase to anti-phase. Discrete Relative Phase (DRP) has been further developed and used for evaluating phasic differences between pelvic and thoracic rotations [1, 2, 6-11]. In these experiments, the coordination in terms of phasic differences between the two segments at each moment of a stride cycle had been computed. Once this has been computed, the mean value of these had been regarded as indices of coordination mode, and their standard deviation as indices of coordinative stability [6]. These studies have shown and discussed the uses of DRP, and the calculation methods implemented. There are many other studies which involve the use of DRP. However, they concentrate significantly on the biomechanical side of the results concerning the participants involved and only a small amount on mathematical modelling.

Continuous Relative Phase (CRP) is used to establish the phasic differences between two oscillating segments or joints, which are sampled at intervals throughout a complete cycle. CRP has also been used for assessing phasic differences between pelvic and thoracic rotations [6, 8, 12]. CRP was initially established for assessing coordination of finger oscillations [2, 3], since then it has been used for various applications including running injuries [4], coordination patterns in walking and running [13], and intralimb coordination following obstacle clearance [5]. One area of argument is the most appropriate use of normalization once CRP has been calculated. Two normalization methods are typically used to scale data to the unit phase space [4, 14] to control for any spurious oscillations when CRP is calculated. Other studies have argued against normalization in favour of maintaining the original topology or aspect ratio of the data [15, 16]. Peters et al. [17] concluded that CRP information would be subjective if no normalization is used to account for frequency differences in the component oscillators. Kurz and Stergiou [16] recommended differences in the configuration of the non-normalized and normalized. This study also compared CRP with a combination of two different amplitude normalization techniques and two different phase angle definitions. The differences between the methods were also assessed using root-mean-square (RMS) values. These values indicated profound differences in the CRP curve when the phase angle was normalized, and a phase angle was calculated relative to the right horizontal axis. The study also concluded that normalization is not necessary because the arctangent (or inverse tangent) function accounts for the differences in amplitudes between the segments.

Vector coding uses relative motion plots commonly referred to as angle-angle diagrams as they use the angles of two joints plotted against each other as the first step. Vector coding has had a significant amount of development since it was invented as a chain encoding method by Whiting and Zerniche [18]. Whiting and Zerniche developed a structural pattern recognition method for the quantitative determination of equivalence or similarity between movement patterns. This method superimposed a grid on the angle-angle diagrams and transformed it into discrete numerical codes between 0 and 7 starting at one point (A) and ending at a second point (B) and quantifying the direction of change in the angle-angle diagram [18, 19]. This method had been used in the study of locomotion and due to the subtle differences in the angle-angle diagram, this has meant that important information may be lost, as well as the fact that this technique required data points to be equally spaced, which is not always the case in human movements. This limitation was then addressed by Sparrow et al. [20] who developed a vector coding technique where the angle between the consecutive data points on the angle-angle diagrams were calculated. This vector angle is referred to as the coupling angle. This development, where the coupling angle is derived, was used to assess variability or similarity in angle-angle diagrams across multiple gait cycles. However, Tepavac and Field-Fote [21] identified the following problems with this technique:

1. The two trajectories of interest must have an equal number of data points.
2. It can only compare two trajectories at a time.

Tepavac and Field-Fote address these concerns, where Hamill et al. [22] and Heiderscheit et al. [23] both proposed subtle alternative techniques in which the coupling angle was defined as the orientation of the vector between two adjacent points on the relative phase plots.

Principal component analysis (PCA) is a multivariate statistical analysis technique which has been extensively used in the assessment of gait, but it has had limited application for studying other cyclical movement patterns like repetitive lifting or to identify effects arising from fatigue. There are three main approaches for which PCA has been implemented in gait analysis; they are:

1. The first is when PCA is applied to derived representations of the gait rather than directly to the signal [24-26].
2. The second exploits PCA for the direct dimensionality reduction and interpretation of multiple gait signals [27, 28].
3. The third facilitates the analysis of the entire waveform, retaining potentially valuable temporal information [29, 30].

1.3 Research Objectives and Methodology

The main aim of this research was to investigate and compare existing coordination analysis techniques for their adaptability or modification for the assessment of fatigue. This research focused on using data collected from the lower extremity coordination of the thigh and knee joints of the right leg in the sagittal plane, as shown in Figure 1.1. The techniques investigated and develop a coordinative variable between the two joints. The coordinative variable, for the differing techniques, included information regarding the angular displacement and the angular velocity of the two joints for a specific task being performed. This will enable researchers to use these techniques in the analysis of biomechanical data relating to the identification of fatigue in multicyclic behaviour.

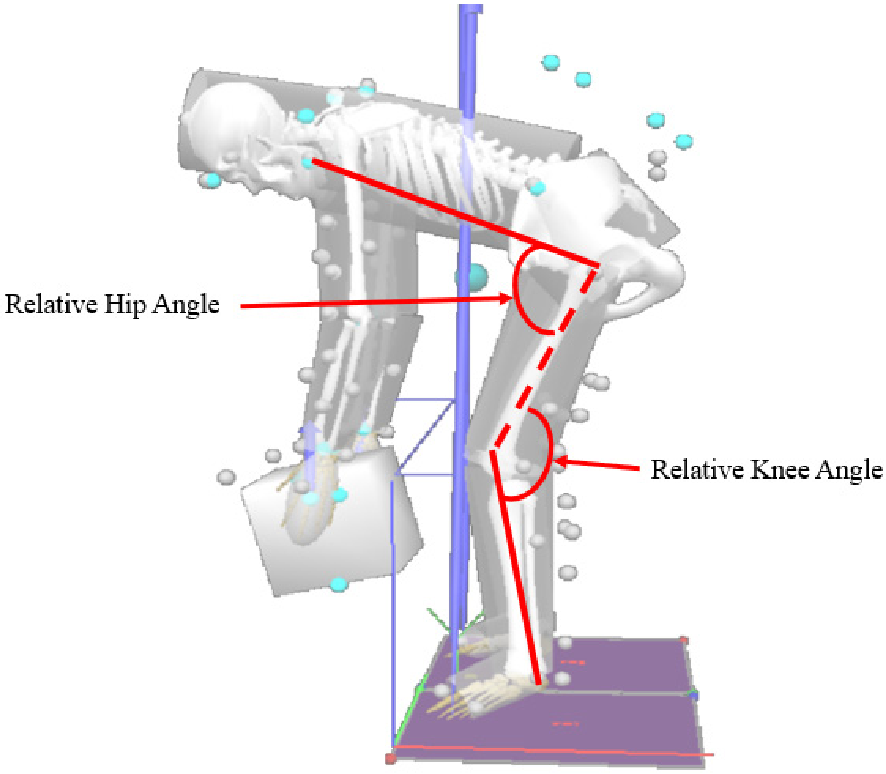

Figure 1.1: The two joints of interest of the lower extremities.

Table 1.1 gives a summary of the parameters used in this research and the possible number of joints/segments that can be assessed for each technique.

Table 1.1: Techniques used in this research.

Technique	Uses Angular Displacement	Uses Angular Velocity	Number of Joints/Segments that can be Assessed.
Discrete Relative Phase	✓	×	2
Continuous Relative Phase	✓	✓	2
Vector Coding	✓	×	2
Principal Component Analysis	✓	✓	2+

Appendix A shows the raw kinematic data collected for the knee and hip angular displacement and velocities from Participant A. Each lift has a total of 101 data points, and the participant was required to perform the lifting task a total of 21 times.

The overall thesis covers and explains in detail the various techniques researched, along with the interpretation of the data. Chapter two describes the kinematic data collection process and explain how the angles of the joints of interest are derived using both mathematics and motion-capture system for a fatiguing task. Chapter three will outline Discrete Relative Phase for its use in joint coordination analysis, along with the mathematical equations used in this research with relation to the identification of fatigue in multicyclic behaviour. Chapter four will cover Continuous Relative Phase, the numerical analysis of the two joints of interest and interpretation of the results. Chapter five will analyse the use of Vector Coding in its ability to also assessing inter-joint coordination with the results analysed and discussed for its merits. Chapter 6 will cover the analysis and results for the final technique used called Principal Component Analysis.

The overall findings, conclusions of this research and possible future work are presented in Chapter 7.

Chapter 2
Kinematic Data Collection

This chapter explains how the angular displacement and angular velocity is derived from human participants using motion-capture technology and the critical aspects of data collection. Also described is the specific lifting task which participants carried out and which is assessed using different analysis techniques in the subsequent chapters within this thesis. Discrete Relative Phase, Continuous Relative Phase, Vector Coding and Principal Component Analysis methods use the data set from one participant to outline the differences in the processes, while the initial data remains unchanged.

2.1 Anatomical Frame of Reference

Essential for comparing data between participants and research investigations are well defined anatomic axis systems that meet specific criteria, which are as follows:

1. To be consistent with the conventions of mechanics, the coordinate directions must comply with the right-hand rule.
2. An axis system must be defined using three non-colinear anatomical landmarks that are on a rigid body and as far apart as possible.
3. The coordinate direction should be selected so that when the body is in the standard anatomical position, the x-direction most closely extends from the posterior to anterior, the y-direction from right to left, and the z-direction from inferior to superior.

The standardization of frames of reference date back to the 1980's [31]. The conventional frames of reference for biomechanics are shown in Figure 2.1. The three planes in which a human body can be referred are:

1. Frontal plane.
2. Transverse plane.
3. Sagittal plane.

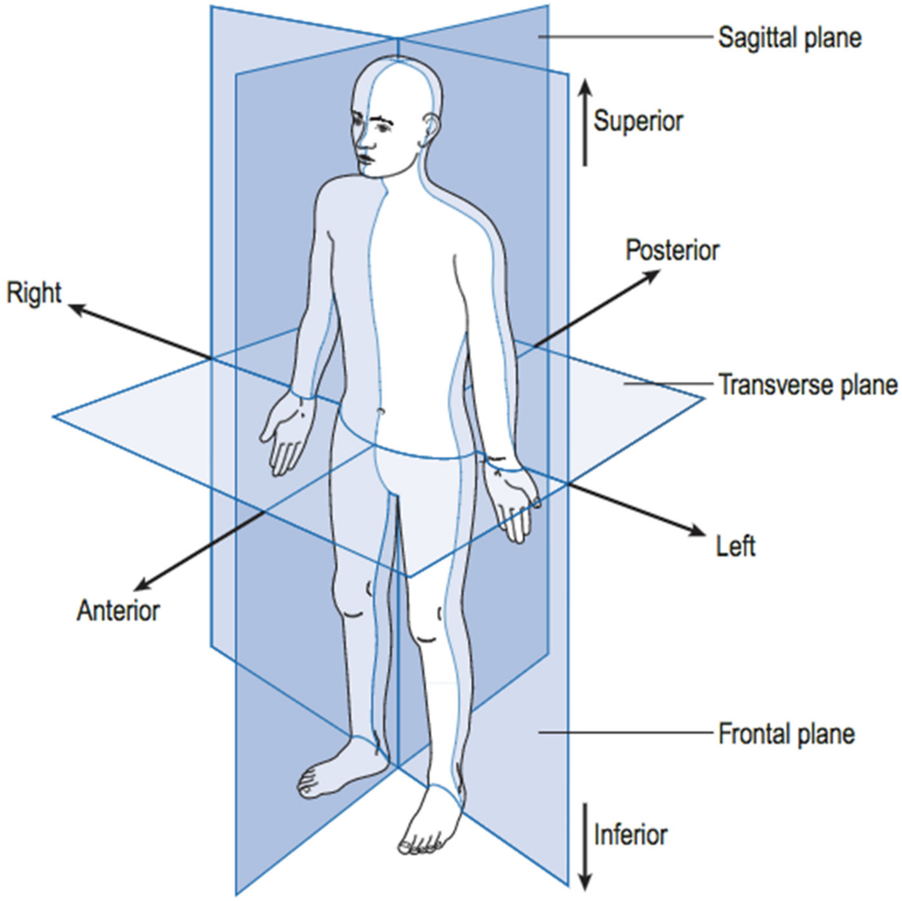

Figure 2.1: The anatomical position showing the three reference planes along with the six fundamental directions.

When a human body is referred to within any of the three planes, there are an additional six terms used to describe the body in detail, which are:

1. Superior.
2. Inferior.
3. Posterior.
4. Anterior.
5. Right.
6. Left.

The participants performed the lifting task in the sagittal plane, shown in Figure 2.2 shows a visual representation of the participants performing the required lifting task in the sagittal plane. The sagittal plane within this experiment is referred to as the Z-X axis.

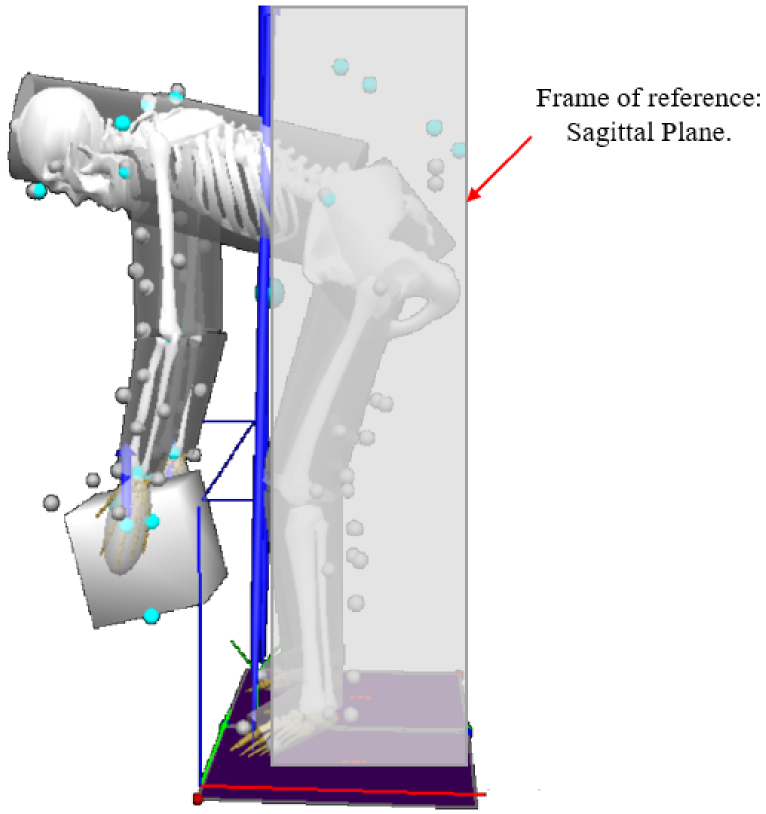

Figure 2.2: Computer simulation figure of a participant performing the lifting task in the sagittal plane.

2.2 Coordinate System

With the collection of the raw data relating to biomechanical systems, once the frame of reference has been established, the coordinate system needs to complement the chosen frame of reference. The two coordinate systems are:

1. Global Coordinate System (GCS).
2. Local Coordinate System (LCS).

The GCS will display the frame of reference and is shown in Figure 2.3. Each participant has reflective markers placed on various parts of their segments. As only the sagittal plane is in use, each marker will have two degrees of freedom (DOF). The two DOF in this research correspond to the Z-X axis. The Local Coordinate System is to describe the position of the segment itself; an angle θ describes the orientation with respect to the GCS, shown in Figure 2.3.

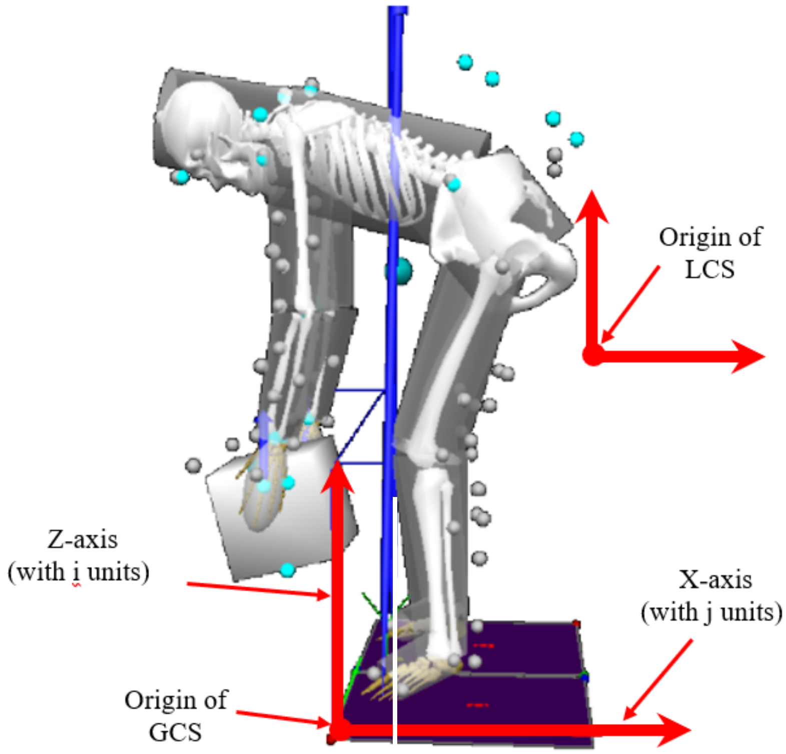

Figure 2.3: Global Coordinate System (GCS) and Local Coordinate System (LCS) for a participant performing the required lifting task.

2.3 The Repetitive Lifting Task and Setup

The Health and Rehabilitation Research Institute at Auckland University of Technology conducted the testing and collection of the data from a total of 28 participants [32]. The 28 participants were split between 14 in a younger group with a mean age of 24.4 years old and older group with a mean age of 47.2 years old. The research institute received ethical approval from the Auckland University of Technology's Ethics Committee to carry out the testing and collection of the data. The institute provided the data for this research in a raw format with no personal identification attached.

Participants lifted a box weighing 13 kg at a frequency of 10 lifts/min. The box (300 mm × 200 mm × 255 mm) was held by two cylindrical handles (28 mm diameter) extending 60 mm from either side of the box, at the height of 170 mm above its base. The box was lifted from a platform 150 mm above the floor to an upright standing position, shown in Figure 2.4.

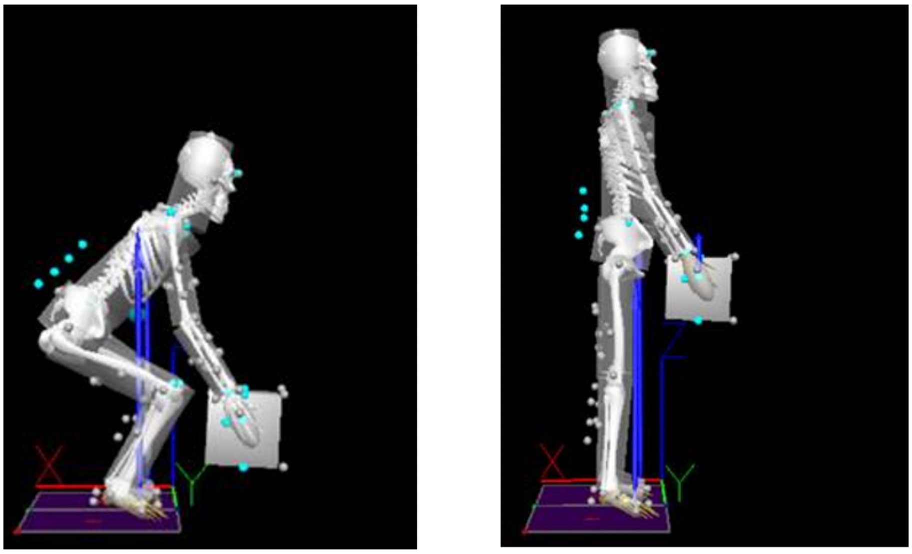

Figure 2.4: Example of participants in the initial starting position (left) and the upright standing position (right) marking the end of one complete cycle.

Participants were excluded from the study if they had undergone previous spinal surgery; a back complaint within the last 6 months; a cardiovascular or neurological condition; or a musculoskeletal injury at the time of the study. None of the participants was experienced in manual handling, i.e. none regularly undertook manual handling during their regular job.

2.4 Relative Joint Angles

Relative joint angles are defined as the displacement of the joint angles relative to each other in state space. Movement is defined as the change in position in the state space.

2.5 Angular Velocity Derivatives

Velocity is the time derivative of displacement, defined as the rate of change of velocity with respect to time, given in equation (2.1) is an example of finite difference calculus with the method used as the central difference method.

$$\omega_i = \frac{\theta_{i+1} - \theta_{i-1}}{2(\Delta t)} \tag{2.1}$$

where ω is the angular velocity, θ represents the angular position, Δt represents the time duration between adjacent samples, i represents the instant in time that is being analysed.

In summary, motion-capture systems provide an efficient way of data collection from human participants. Detailed understanding of the equations and methods in which motion-capture systems employee are imperative for a thorough understanding of how mathematical analysis can enable an accurate representation of the movement tasks performed. Principal Component Analysis demonstrated merits in the analysis of biomechanical data sets, and it warrants further investigation for a complete overview of the capabilities regarding correlation and covariance matrix, dimensionality reduction when a comparative analysis of several groups is required.

Chapter 3
Discrete Relative Phase

Relative phase techniques provide a coordinate variable which can be assessed and investigated to provide insight into the coordination of two segments or limbs for an individual. This chapter explains the Discrete Relative Phase (DRP) methodology and equations used for the analysis of biomechanical data sets. DRP is a point estimate technique which investigates the latency of one segment with respect to another [33]. The chapter concludes with the interpretation of DRP, using the data set for participant A.

3.1 Background

DRP was first introduced by Haken et al. in 1985 [1], and since then, it has been reviewed, expanded and modified to consider technological advancements, namely the introduction of motion analysis systems. Haken and colleagues first proposed phase as an order parameter for the following two reasons:

1. Considering the components of a system, phase would be an accurate reflection of the cooperativity among the parts that would make up a whole system. Thus, in a manner consistent with synergetics, that the configuration of the subsystem specifies their phase relation, and conversely, that the phase variable specifies the spatiotemporal ordering of the subsystem.
2. The order parameter, the relative phase, changes much more slowly than the variables describing the behaviour of the individual components of the system, i.e. velocity. Which is consistent with the notion that phase remains invariant across transformations in many motor activities that involve very different anatomical substrates.

Haken and colleagues then developed a mathematical description of the main qualitative features of their system, human hand motion, considering the above two points. Figure 3.1 shows a visual representation of the system in which the earliest version of relative phase was developed, along with their mathematical description of the system.

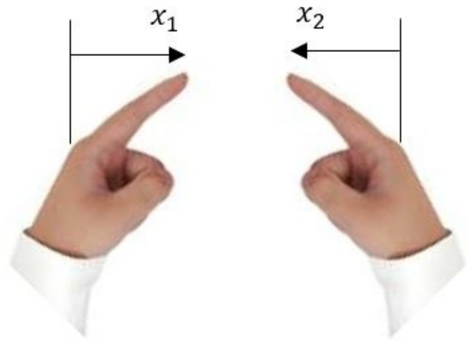

Figure 3.1: Haken et al. human hand system mode. Showing fingertips of the left and right hand in the symmetrical (in phase, homologous) model.

The elongations of the fingertips x_1 and x_2 shown in Figure 3.1 are used to define the relative phase ϕ. Assuming the motion of the hands is more and less harmonic, so that:

$$x_1 = r_1 \, cos(\omega t + \phi_1) \quad (3.1)$$

$$x_2 = r_2 \, cos(\omega t + \phi_2) \quad (3.2)$$

where ω is the primary angular frequency of the hand movement, where the amplitudes r_1, r_2 and the phases ϕ_1, ϕ_2 are time-dependent quantities whose time dependence is assumed to be much slower than that defined by ω. The relative phase is represented by:

$$\phi = \phi_2 - \phi_1 \quad (3.3)$$

As shown in synergetics, in many cases the equations for order parameters are of the form:

$$\phi = \frac{\partial V}{\partial \phi} \quad (3.4)$$

where V is the potential function.

So, the following two assumptions can be made:

Assumption 1. As ϕ occurs as cosine or sine functions, the properties of the physical system must not change when ϕ is replaced by $\phi + 2\pi$.

Therefore, the potential V is periodic:

$$V = (\phi + 2\pi) = V(\phi) \tag{3.5}$$

Assumption 2. Both hands play a symmetric role. In which case, the behaviour of the system must not depend on the way the right and left hand is labelled. This means:

$$V(\phi) = V(-\phi) \tag{3.6}$$

$$V = -a\,cos\,\phi - b\,cos\,2\phi \tag{3.7}$$

where *V* is a superposition of two cosine functions. A hysteresis phenomenon occurs between the transitions from the antisymmetric state into the symmetric state for the hand movement. In order to investigate at which value of *b/a* the transition occurs, the extrema of V are investigated, which is defined by:

$$\frac{\partial V}{\partial \phi} = 0 \tag{3.8}$$

Using equation (3.7) and (3.8):

$$-a\,sin\,\phi - 2b\,sin\,2\phi = 0 \tag{3.9}$$

the second term is:

$$sin\,2\phi = 2\,sin\,\phi\,cos\,\phi \tag{3.10}$$

so that equation (3.9) becomes:

$$-a\,sin\,\phi - 4b\,sin\,\phi\,cos\,\phi = 0 \tag{3.11}$$

One set of roots is given by:

$$sin\,\phi = 0 \tag{3.12}$$

so:

$$\phi = 0, \phi = \pm\pi \tag{3.13}$$

The other set of roots is given by:

$$-a - 4b\,cos\,\phi = 0 \tag{3.14}$$

solving for $\cos\phi$:

$$cos\,\phi = -\frac{a}{4b} \tag{3.15}$$

Due to $\cos\phi$ representing the inner maximum of *V*, the transition occurs when these maxima vanish and can no longer be fulfilled by real ϕ. This then provided:

$$\left|\frac{a}{4b}\right| > 1 \tag{3.16}$$

or,

$$|b| < \frac{|a|}{4} \tag{3.17}$$

The transition occurs if $|b|$ drops below the critical value $b_c = \frac{|a|}{4}$. Given that the amplitudes r_1, r_2 decrease with increasing ω, b can be expressed using amplitude $r = r_1 = r_2$ and a critical magnitude r_c so that the potential function is written in the form:

$$V = -a\left(cos\,\phi + \frac{1}{4}\frac{r(\omega)^2}{{r_c}^2}cos\,2\phi\right) \tag{3.18}$$

where r_c is defined as that value of r where the transition occurs.

3.2 Discrete Relative Phase Computation

Using technology such as motion-capture systems, the modelling of kinematic and kinetic data sets has provided researchers with a much more accurate model of the system of interest. The motion-capture system will output the angles throughout the specified cycle. Once these angles have been found, the calculation of DRP is given by:

$$DRP = \frac{(\Phi_{hip(i)} - \Phi_{kn(i)})}{(\Phi_{hip(i)} - \Phi_{hip(i+1)})} \times 360° \tag{3.19}$$

where $\Phi_{hip(i)}$ represents the hip joint angle, $\Phi_{kn(i)}$ represents the knee joint angle during the cycle percentage '(i)'. The DRP results are plotted shown in Figure 3.2 and Figure 3.3.

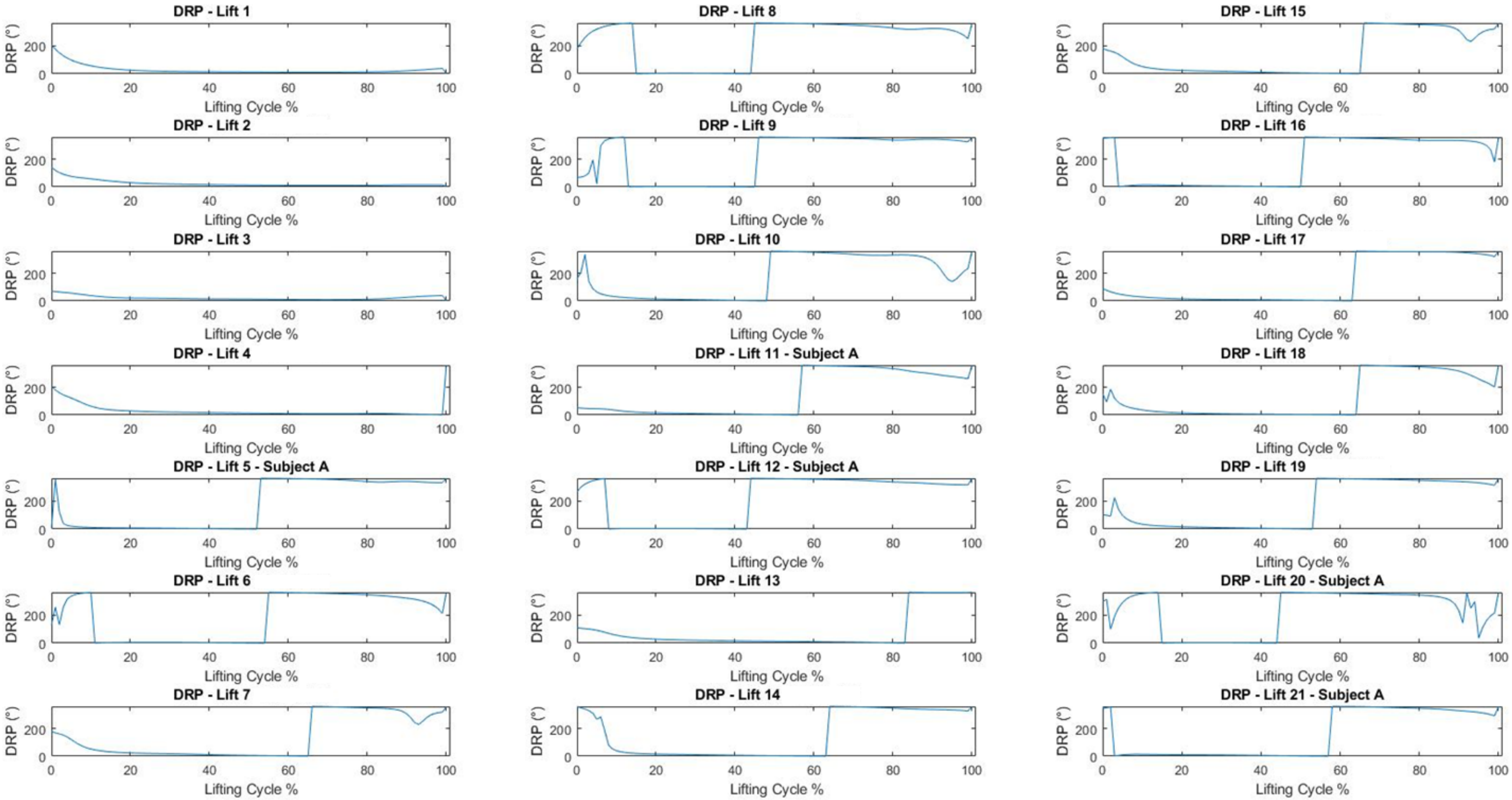

Figure 3.2: *Discrete Relative Phase subplots for Participant A.*

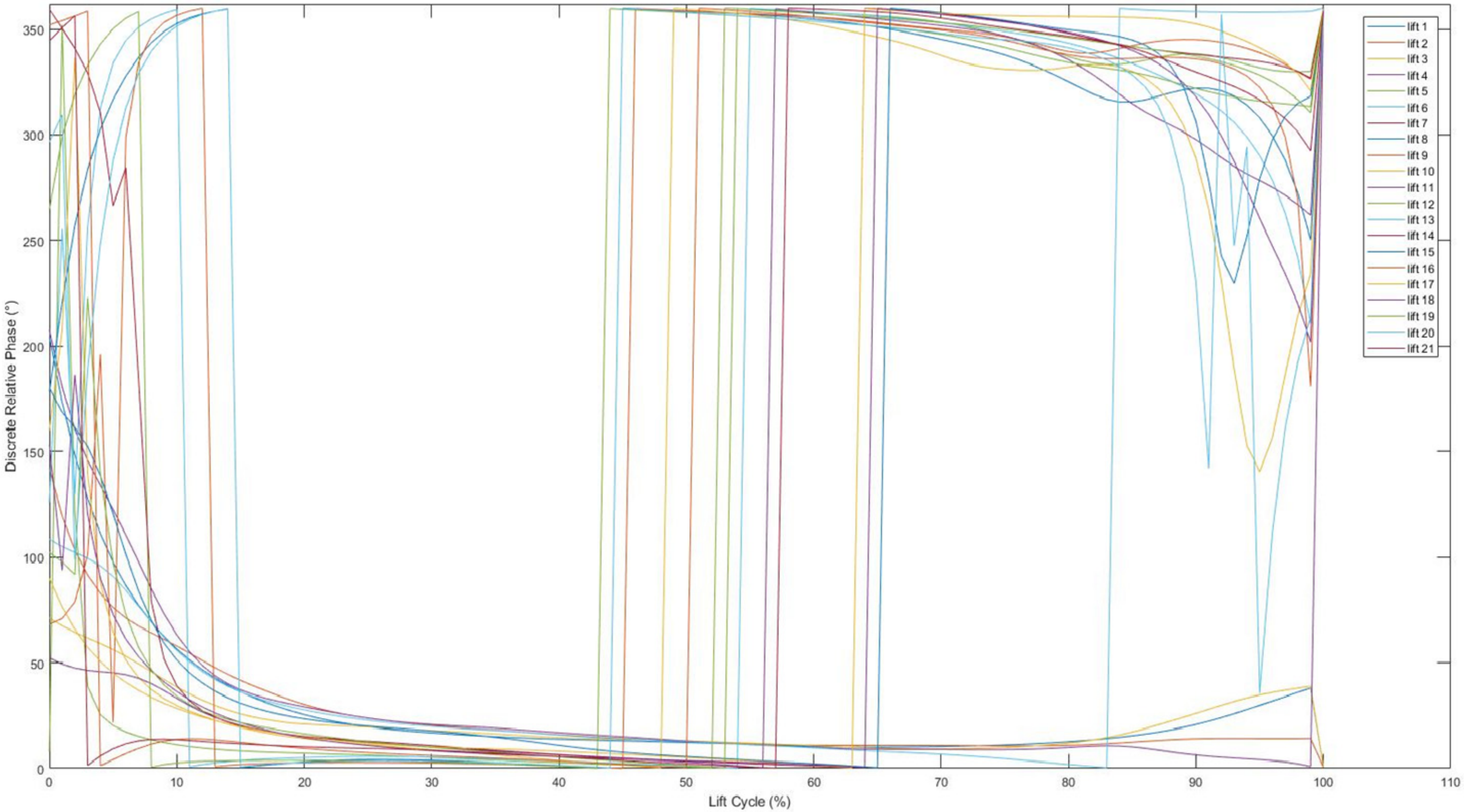

Figure 3.3: Discrete Relative Phase plots for Participant A, showing all the lifts.

3.3 Simplified Flowchart for Discrete Relative Phase Matlab Code

The concept of the software design and development for Discrete Relative Phase is illustrated in Figure 3.4. The final developed Matlab code is given in section B-1 of Appendix B.

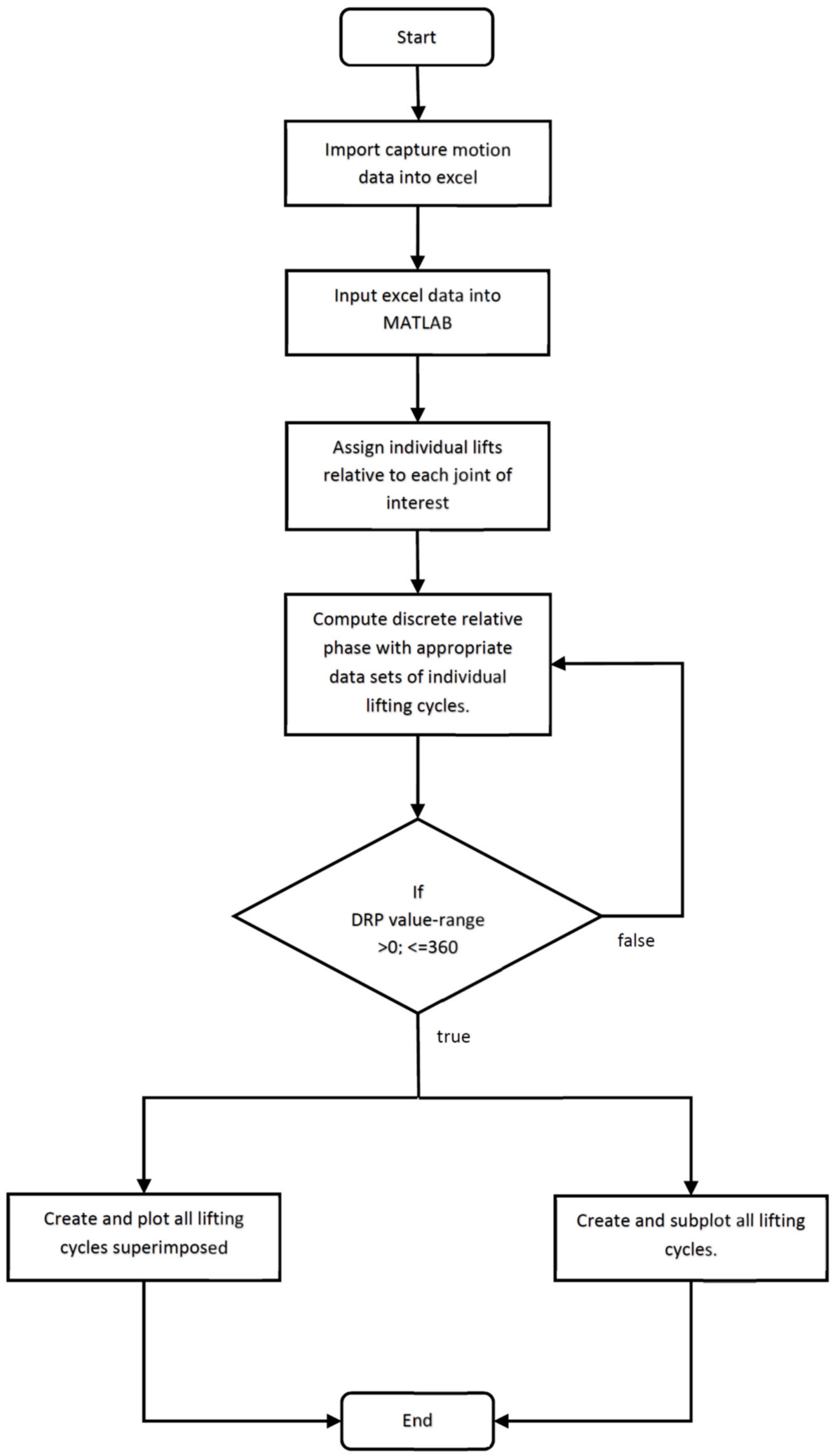

Figure 3.4: Matlab development flowchart for Discrete Relative Phase.

3.4 Interpretation of Discrete Relative Phase Results

Discrete relative phase presents a simple, is an effective way of interpreting inter-joint coordination. DRP is best explained using the subplots, as shown in Figure 3.2, with only the interested lifts superimposed shown in Figure 3.3. When viewing the subplots, lift 1 should be used as a reference point. Lift 1 displays the ideal lifting situation when the participant has not been exposed to any external variables such as fatigue. Lift 1 displays the hip extension leading the knee extension, with a phase difference of approximately 180 degrees, indicating anti-phase, shown in Figure 3.5.

As the cycle is executed, the phase difference proceeds to approximately five degrees, which indicates that the joints are moving almost perfectly in-phase. This ideal lifting coordination is observed up to and including 4th lift, with only slight variations. As the participant proceeds to execute the 5th lift, a dramatic change is shown in the ideal movement pattern. At approximately 50 per cent into the lifting cycle it can be observed that a dramatic shift in the phasic pattern occurs, where the participant proceeds in the ideal movement pattern till approximately halfway through the movement cycle, at which point, it is shown that the phase difference is disturbed and that the knee extension is now leading. This change is observed throughout the rest of the lifting cycles, with only slight variations.

Fatigue would be challenging to assess with the only interpretation of the effects of inter-joint coordination. It can be confidently stated that this shift of phases is not because of limitations of the joints themselves, as it has not only been observed that the participant carry-out the ideal lifting scenario for a total of 4 cycles, but there is a need to be aware of the physical limitations of each of the observed joints. This phasic shift which has been observed from lift 5 to lift 21 is due to an external variable which is not physical but is most likely a combination of multiple factors. It would be advisable to investigate the muscles which surround and aid these joints in performing the tasks required. Electromyography would be needed to adequately assess the effects of observed phasic shift, to enable a more accurate diagnosis of the origin of the observed phasic variation.

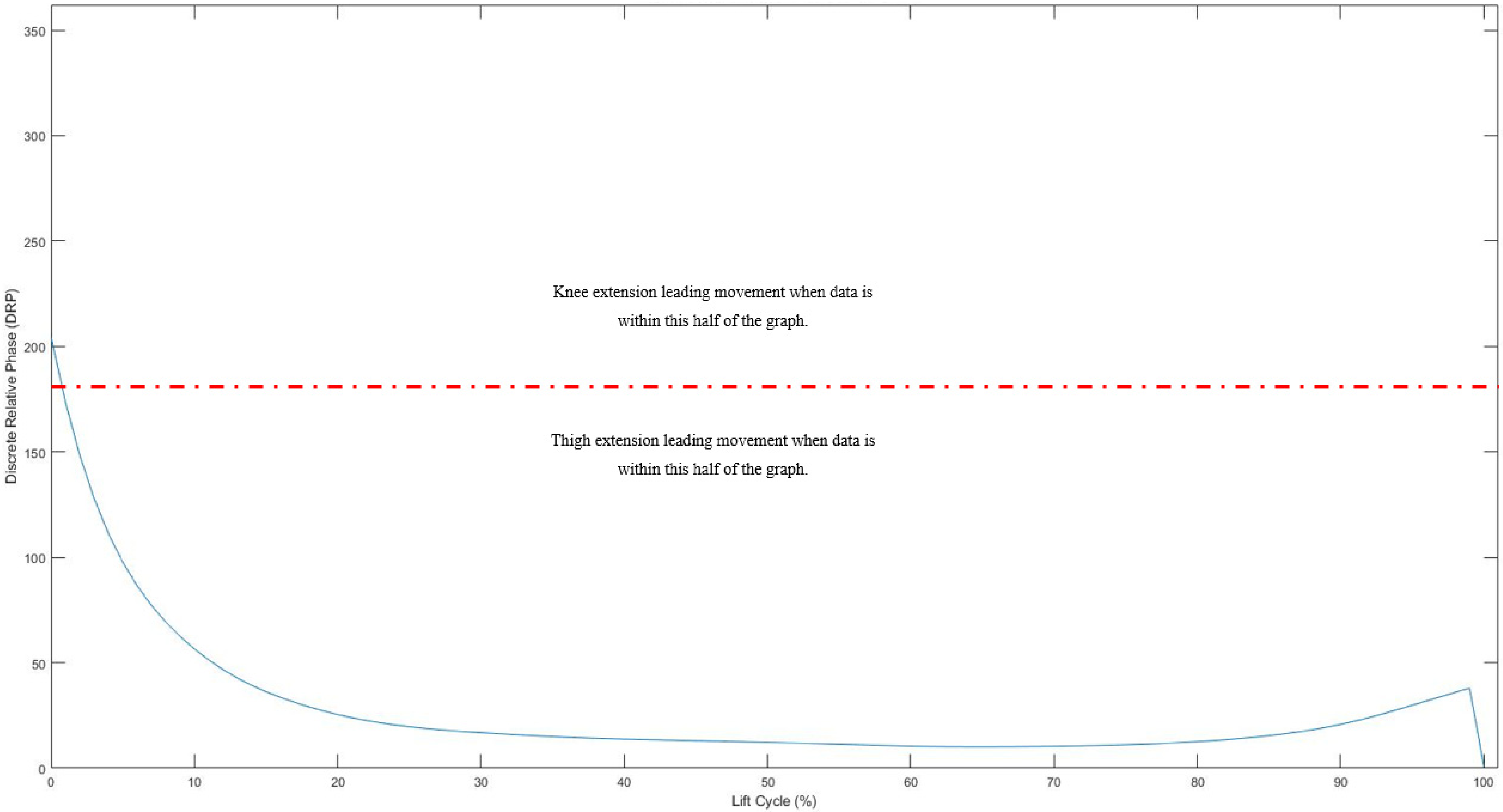

Figure 3.5: Simplified interpretation of Discrete Relative Phase.

As outlined in the previous discussion, DRP provides a simple and effective way of interpreting inter-joint coordination. This is a definite positive advantage of DRP in that even individuals with limited mathematical abilities, can easily explain the results accurately. A primary disadvantage of DRP is that it is a tedious process which must be employed. Usually, with biomechanics, several participants within several groups are compared against each other, which would require the process to be repeated for each of the participants in each of the groups, and then would require a comparison of all the individual lifting cycles of each of the participants, assessed against the rest. Another disadvantage of DRP is its limited capacity, as it can only be used to investigate the coordination of only two joints. The information provided is limited to the angles of these two joints while undertaking one movement cycle.

In summary, DRP provides a useful analysis of the coordination between two joints of interest, the hip and knee joints. The interpretation of DRP can also be used for the examination and investigation of fatigue throughout a complete lifting cycle and assessed across several cycles.

Chapter 4
Continuous Relative Phase

This chapter assesses and investigates the methods and equations used for the computation of Continuous Relative Phase (CRP). CRP is a higher-order resolution of DRP, and this is due to the added dimension of assessing velocity in conjunction with the angular position in the first step of calculating CRP. The chapter assesses the use of normalizing the angular velocity and angular displacement of the joints of interest and assesses the consequences of this with regards to the final interpretation of CRP. The chapter concludes with the final analysis of the results for CRP, both with normalized and not normalized angular displacement and velocity.

4.1 Normalization of Angular Position and Angular Velocity

The effects of normalizing the angular position and angular velocity and the results that they display has been debated by many researchers [15-17]. These researchers discuss the actions or inactions of normalizing the angular position and angular velocity. A significant debate is that the magnitude of angular velocity is not in proportion to the magnitude of angular displacement. Therefore, normalizing the two components would position the magnitude in proportion to each other. The two components are normalized to a range of −1 to +1. The equation used for normalizing angular position is given by:

$$\hat{\theta}_i = \frac{2 \times [\theta_i - min(\theta_i)]}{max(\theta_i) - min(\theta_i)} - 1 \qquad (4.1)$$

where, $\hat{\theta}_i$ is the normalized angular position at the position, i. $min(\theta_i)$ is the minimum angular position during the entire cycle and $max(\theta_i)$ is the maximum angular position during the entire cycle.

The equation used for normalizing angular velocity is given by:

$$\widehat{\omega}_i = \frac{\omega_i}{max|max(\omega_i), max(-\omega_i)|} \tag{4.2}$$

where, $\widehat{\omega}_i$ is the normalized angular velocity at position i, $min(\omega_i)$, is the minimum angular velocity and $max(\omega_i)$ is the maximum angular velocity of the entire cycle.

Normalization of the two components is repeated for each of the two joints of interest. The y-axis was normalized to its highest absolute value to maintain zero velocity at the origin.

4.2 Phase Plane Portraits

Phase plane portraits are then constructed once the normalization of the angular position and angular velocity have taken place. The phase plane portraits for the relevant joints are shown in Figure 4.1 to Figure 4.4. Each phase plot consisted of the angle (θ'_i) on the horizontal axis with its first derivative, angular velocity(ω'_i), on the vertical axis. Following the normalization process, each phase plot had four quadrants with the origin of the *x*-axis at mid-range, and the minimum and maximum values being −1.0 and +1.0, respectively.

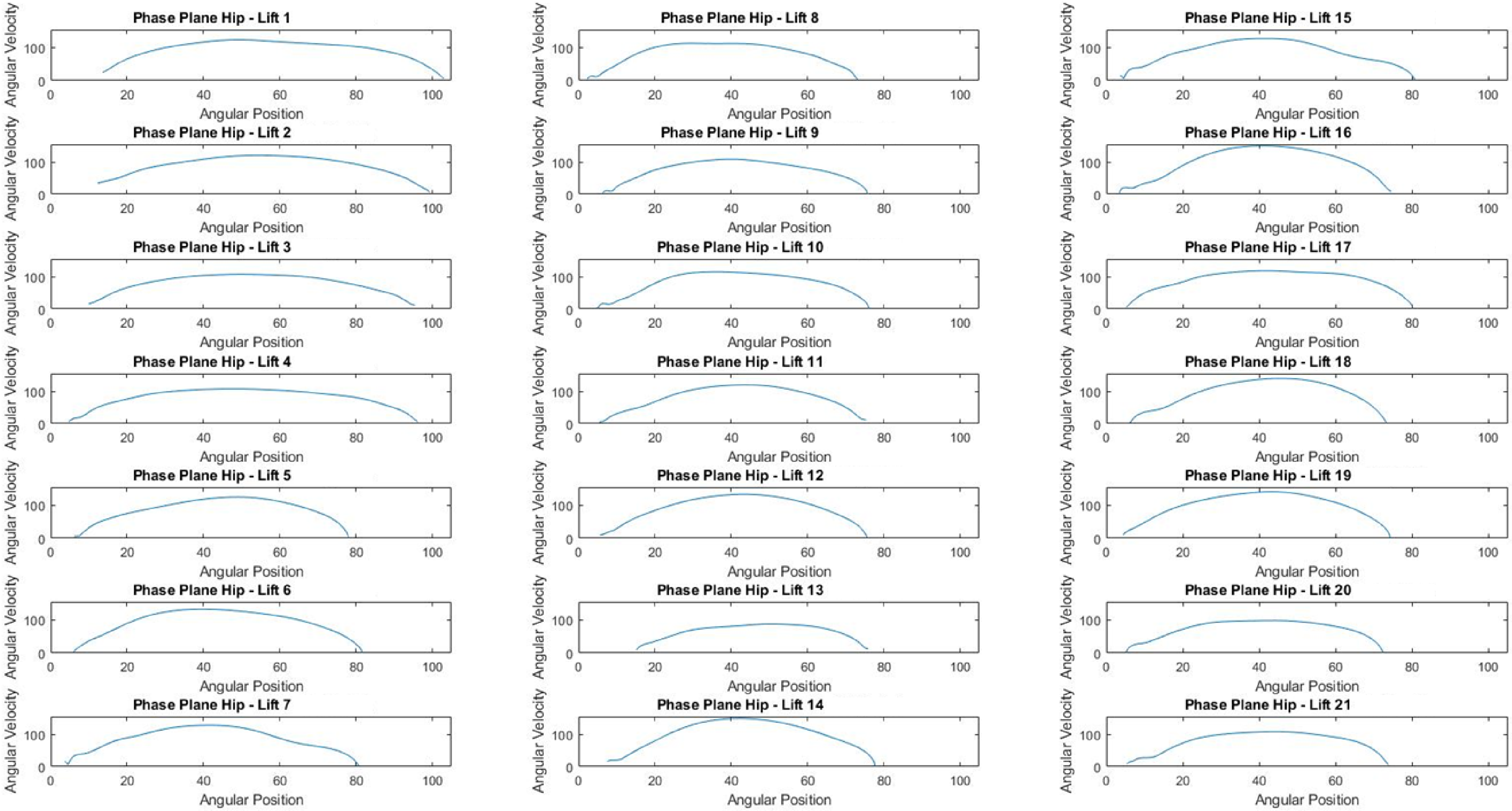

Figure 4.1: Phase Plane subplots of Participant A Hip – Actual Angular Velocity against Angular Displacement.

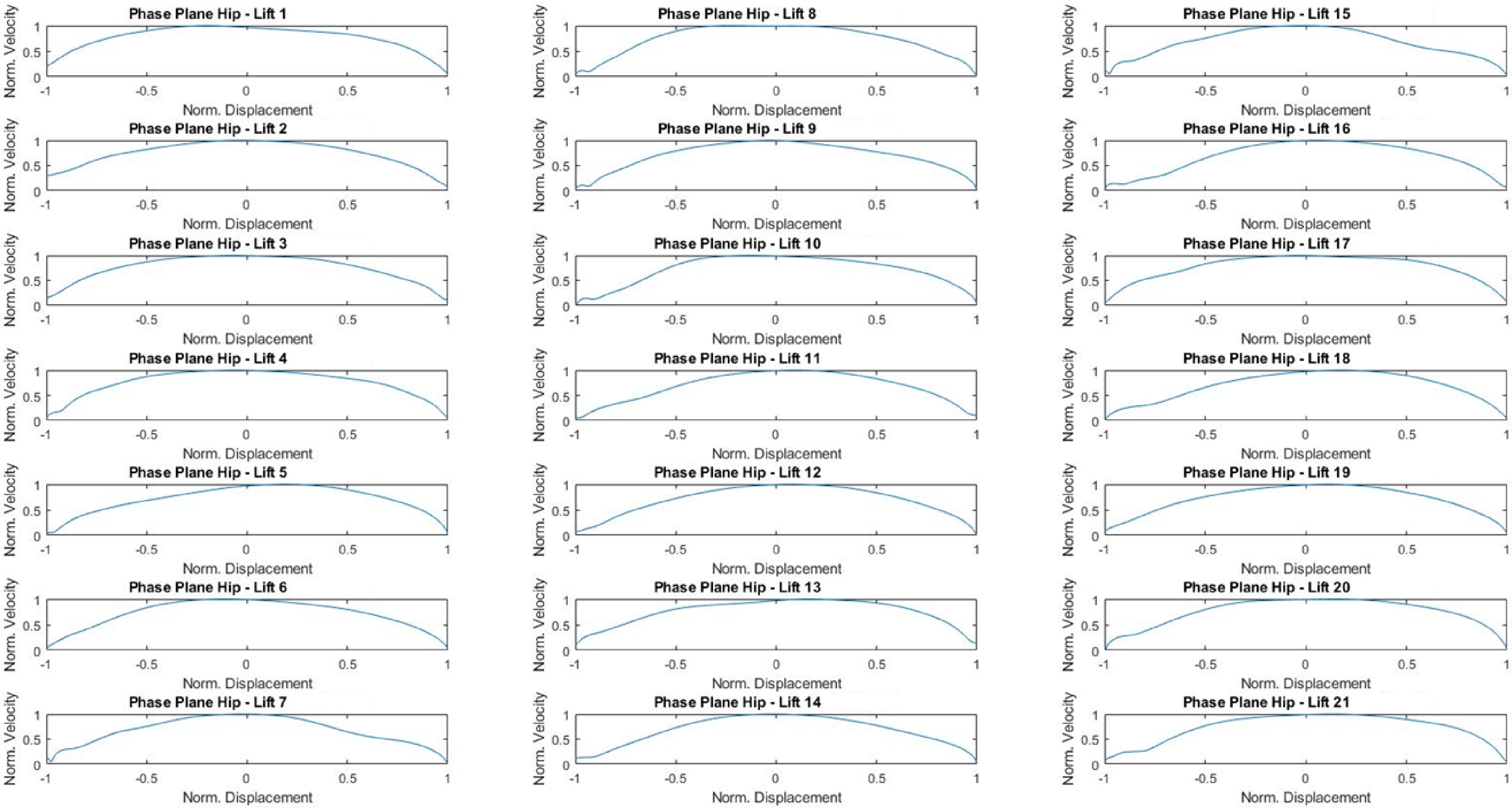

Figure 4.2: Phase Plane subplots of Participant A Hip − Normalized Angular Velocity against Angular Displacement.

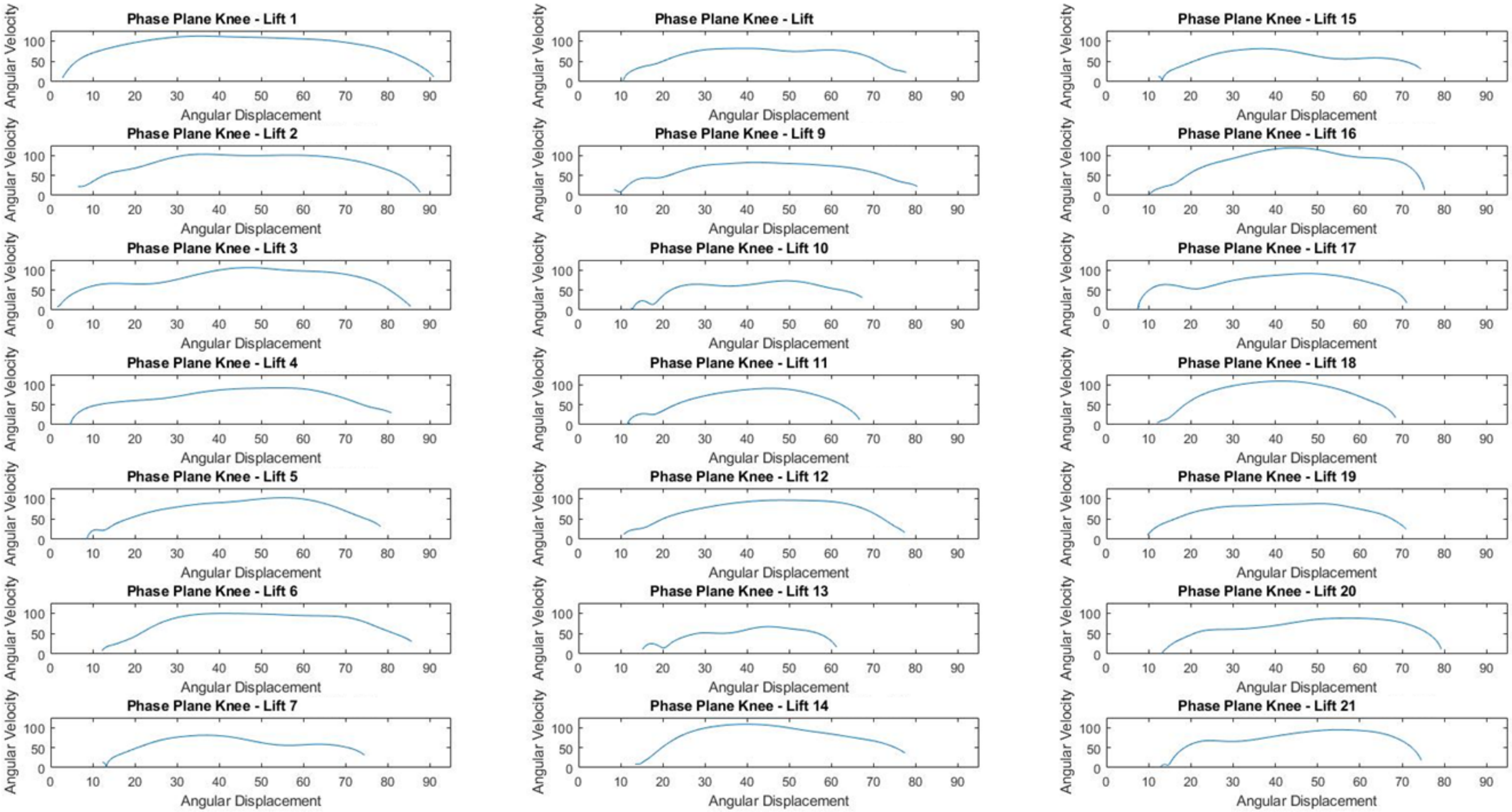

Figure 4.3: Phase Plane subplots of Participant A Knee – Actual Angular Velocity against Angular Displacement.

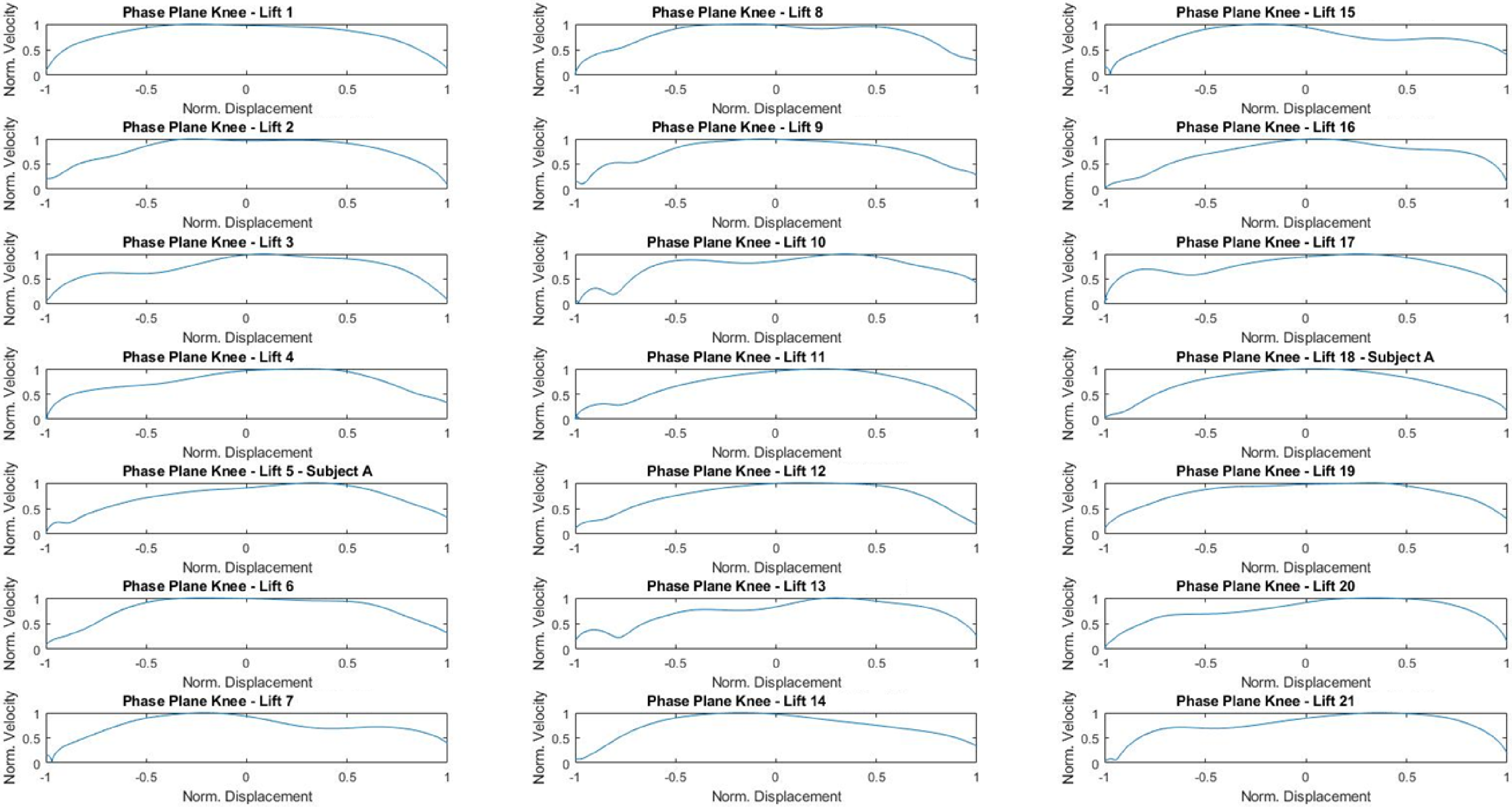

Figure 4.4: Phase Plane subplots of Participant A Knee − Normalized Angular Velocity against Angular Displacement.

4.3 Phase Angle

Once the normalization of the angular position and angular velocity is completed for the two joints, a cooperative variable is calculated for each joint. This cooperative variable is named the phase angle. The phase angle is calculated for each joint, and it provides a relationship for the joint with respect to the angular position and angular velocity during the lifting cycle. The phase angle was defined as the angle between the right horizontal and a line drawn from the origin to specific data point (θ_i, ω_i) and is given by:

$$\phi_i = tan^{-1} \frac{\omega_i}{\theta_i} \tag{4.3}$$

The equation for the phase angle is given as equation (4.3), and it is repeated for both the knee and hip. The phase angle portrait subplots for each lift are shown in Figure 4.5 and Figure 4.6, the phase angle calculation for each joint is the final component which is needed for the calculation of CRP

.

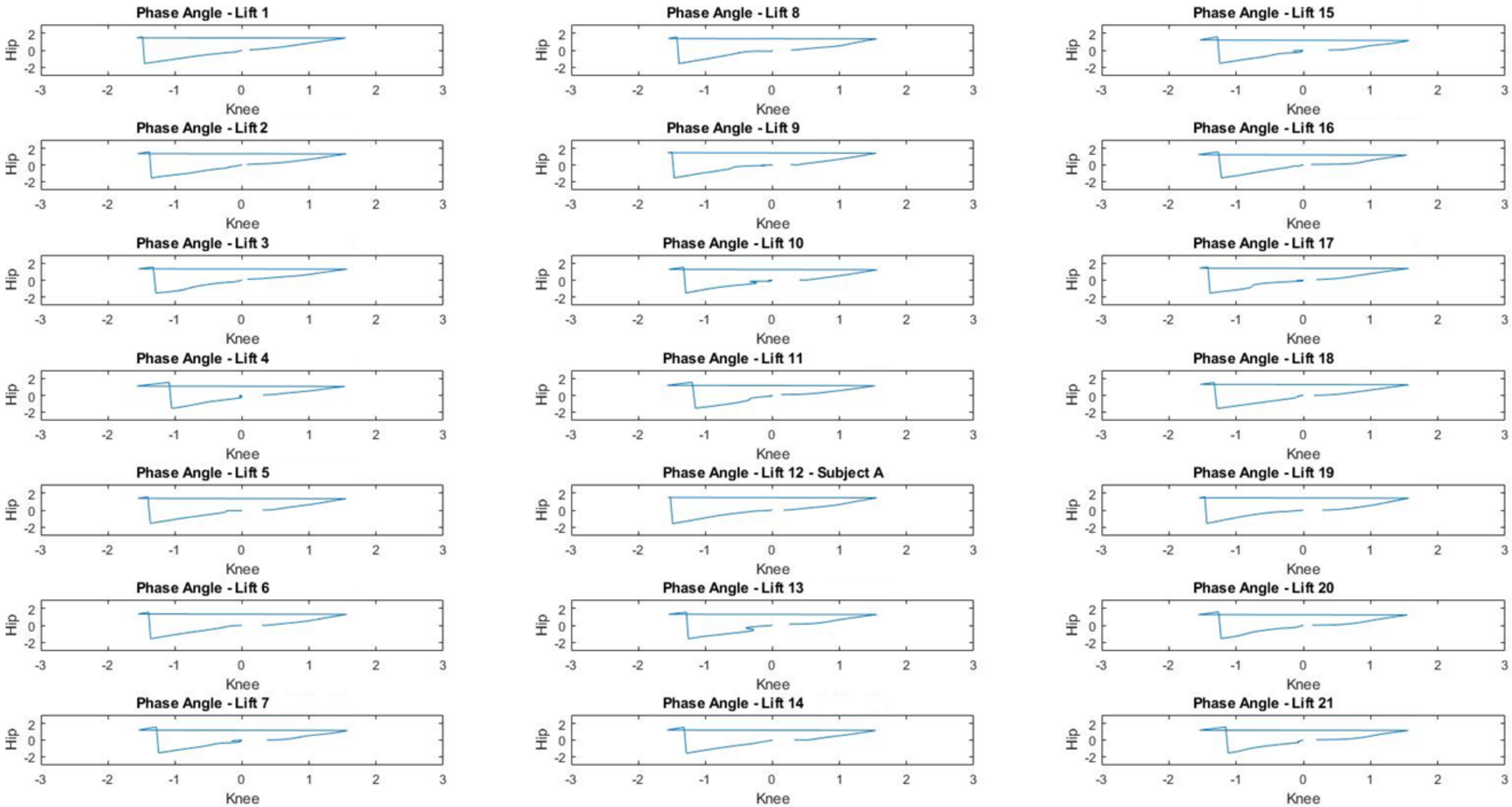

Figure 4.5: Phase Angle Portraits of Participant A for all 21 lifting cycles.

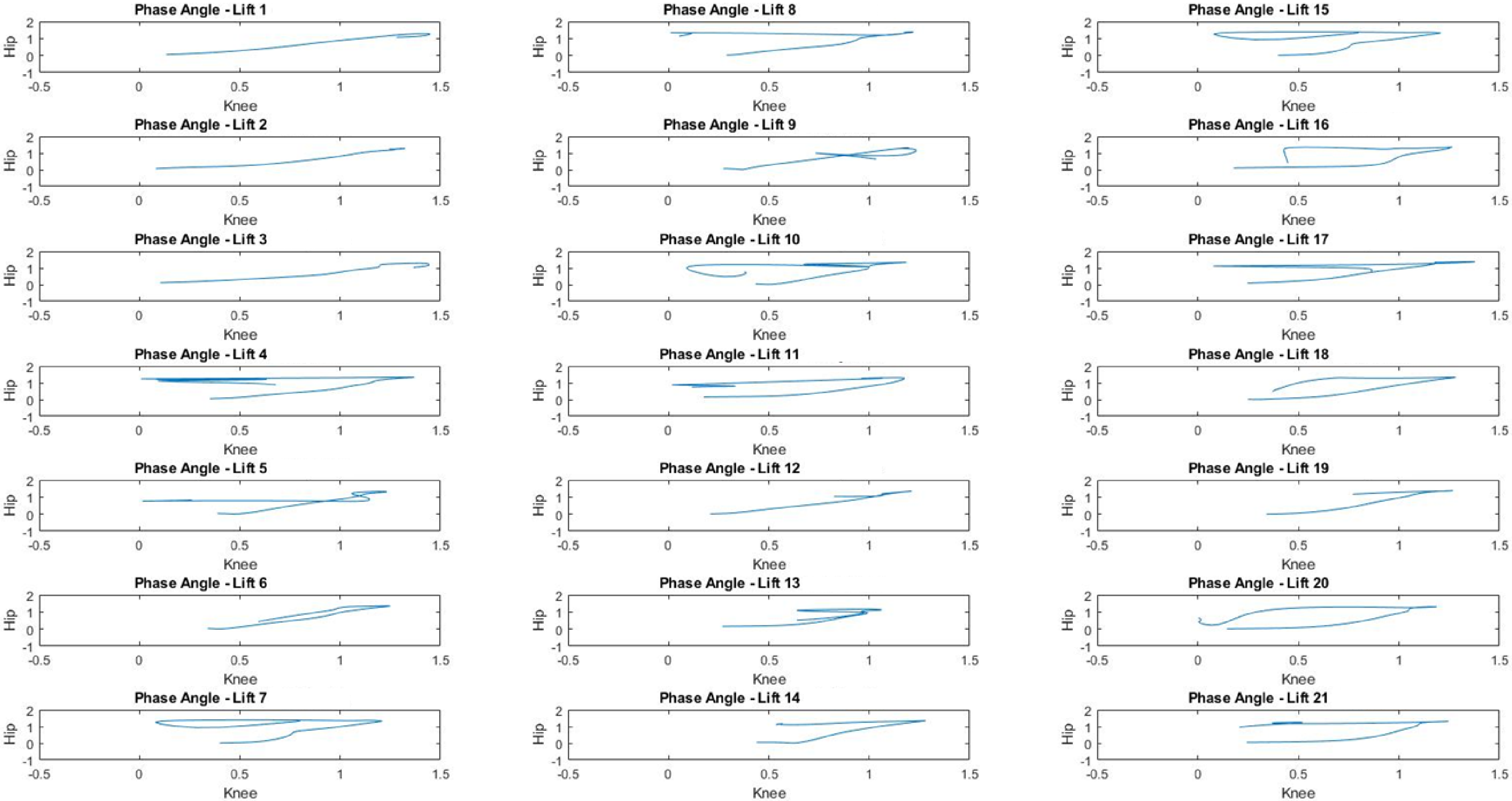

Figure 4.6: Phase Angle Portraits of Participant A for all 21 lifting cycles – Normalized.

4.4 Continuous Relative Phase Computation

Following the calculation of the phase angle, Continuous Relative Phase (CRP) can then be computed using:

$$CRP_i = \phi_{hip_i} - \phi_{knee_i} \tag{4.4}$$

It is important to note that when computing CRP, the distal joint should be subtracted from the proximal joint, to ensure accurate CRP results. CRP was defined as the difference between the normalized phase angles of the two joint motions throughout the lifting cycle. In each coupling of the lower extremity joints, the distal segment was subtracted from the proximal. A CRP of 0° indicated the respective joints were in-phase. As CRP increases or decreases, it would show the joints would be more out of phase until a CRP of 180° would indicate an anti-phase coupling. A positive CRP showed that the proximal joint had a more significant phase angle, while a negative CRP indicated that the distal joint had a greater phase angle. The results of the CRP are shown in Figure 4.7 to Figure 4.10.

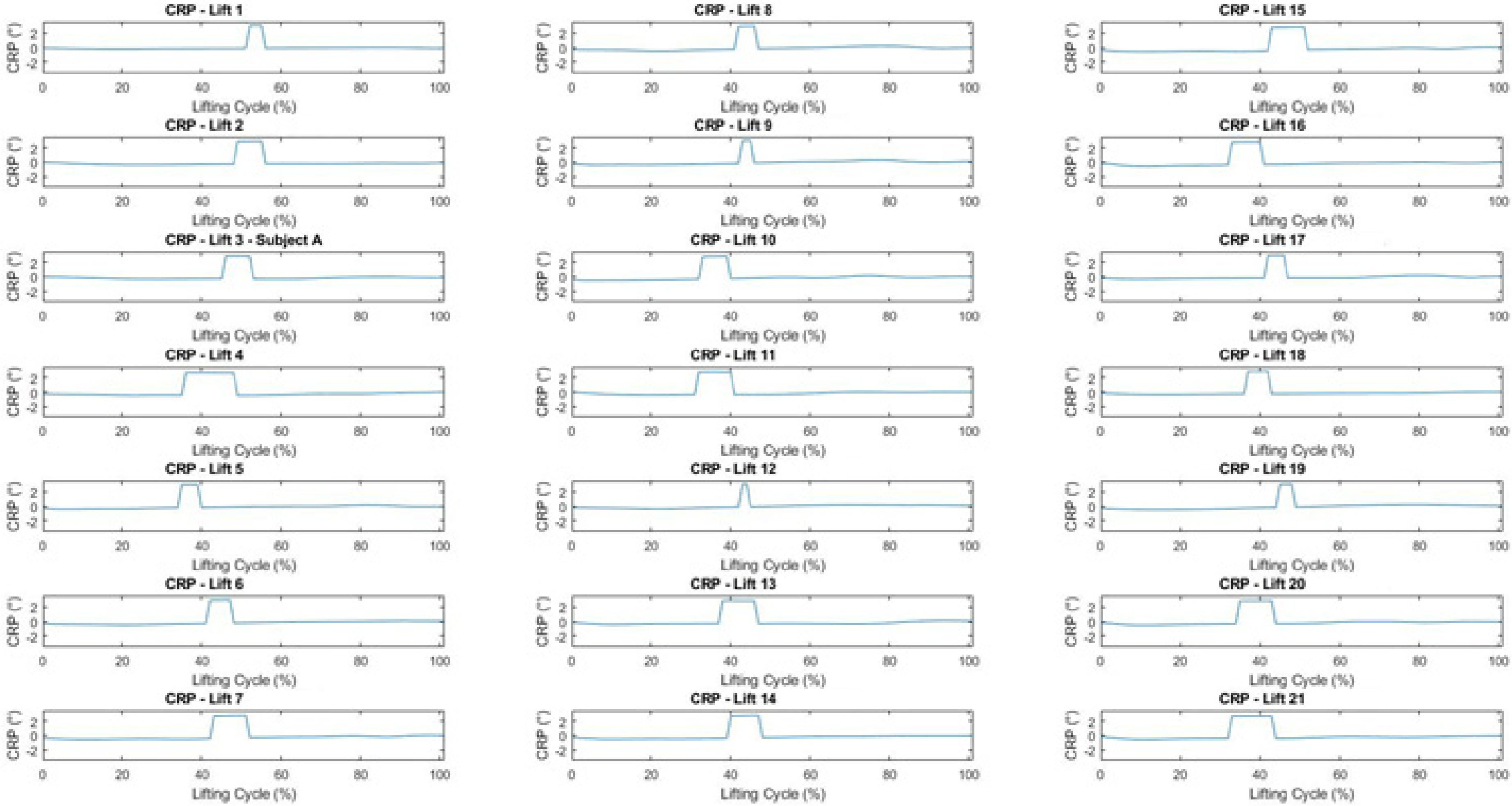

Figure 4.7: Continuous Relative Phase subplots of Participant A for all 21 lifting cycles.

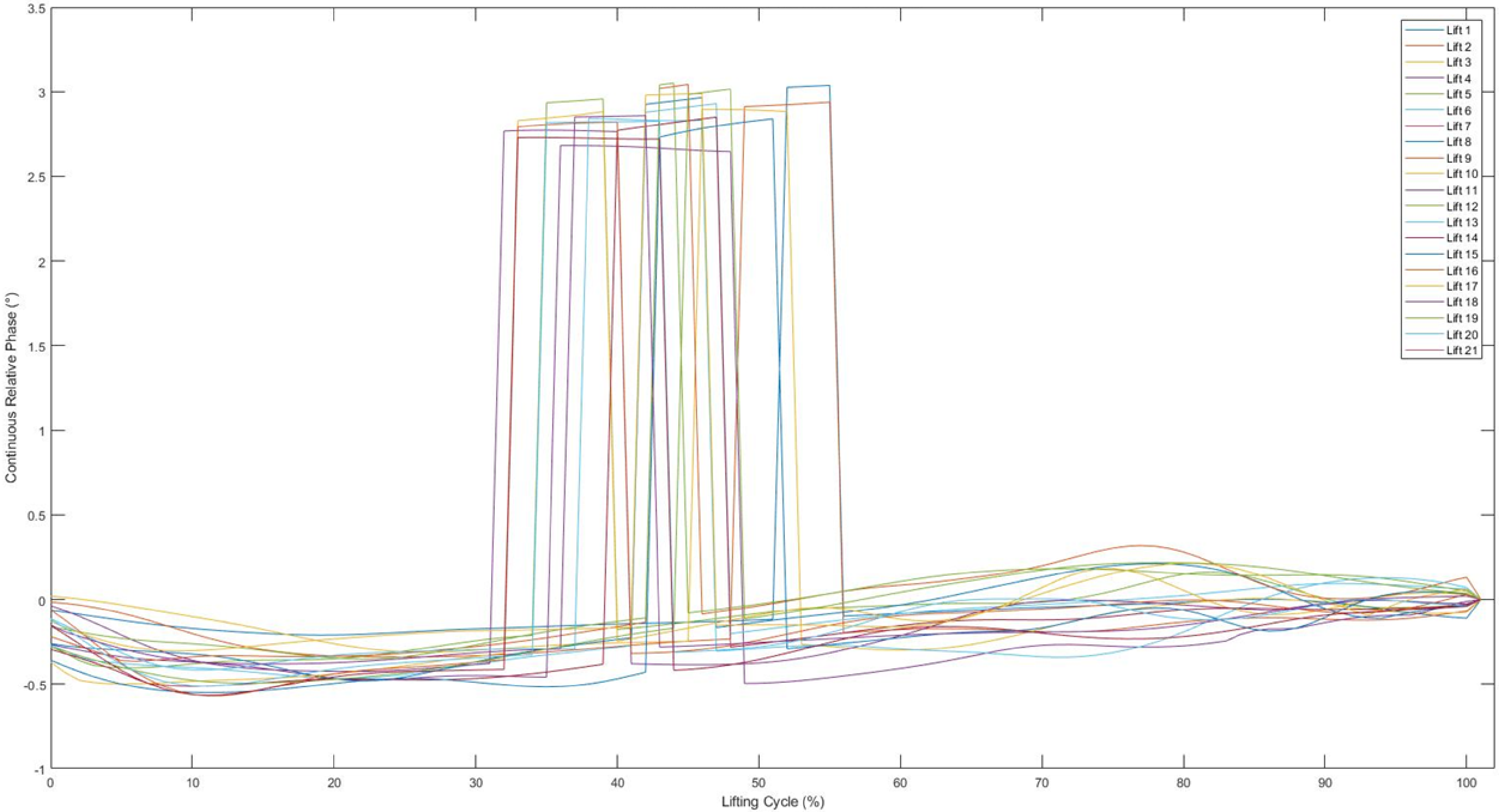

Figure 4.8: Continuous Relative Phase superimposed plot of Participant A, showing all the liftings.

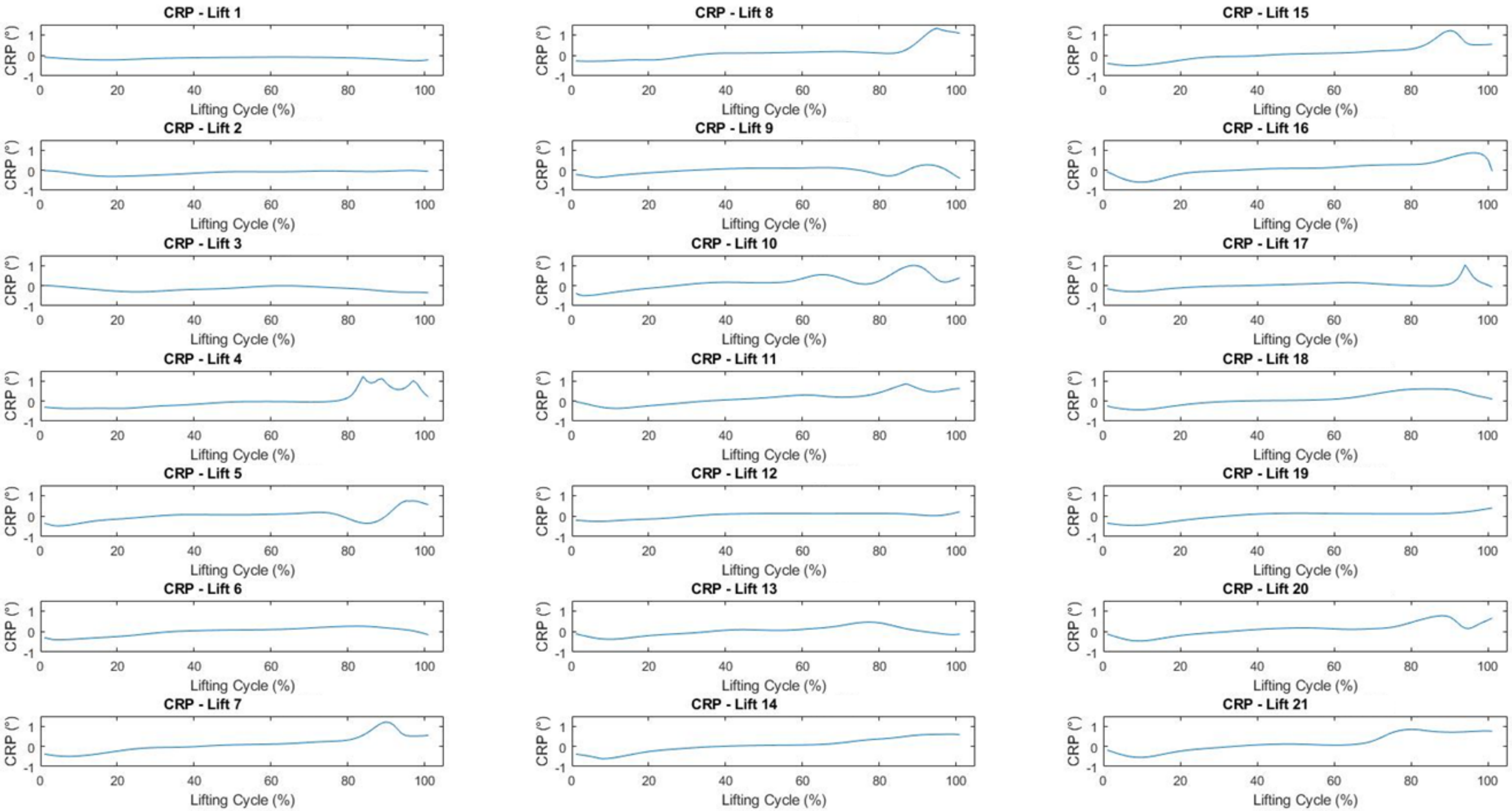

Figure 4.9: Continuous Relative Phase subplots of Participant A for all 21 lifting cycles - Normalized.

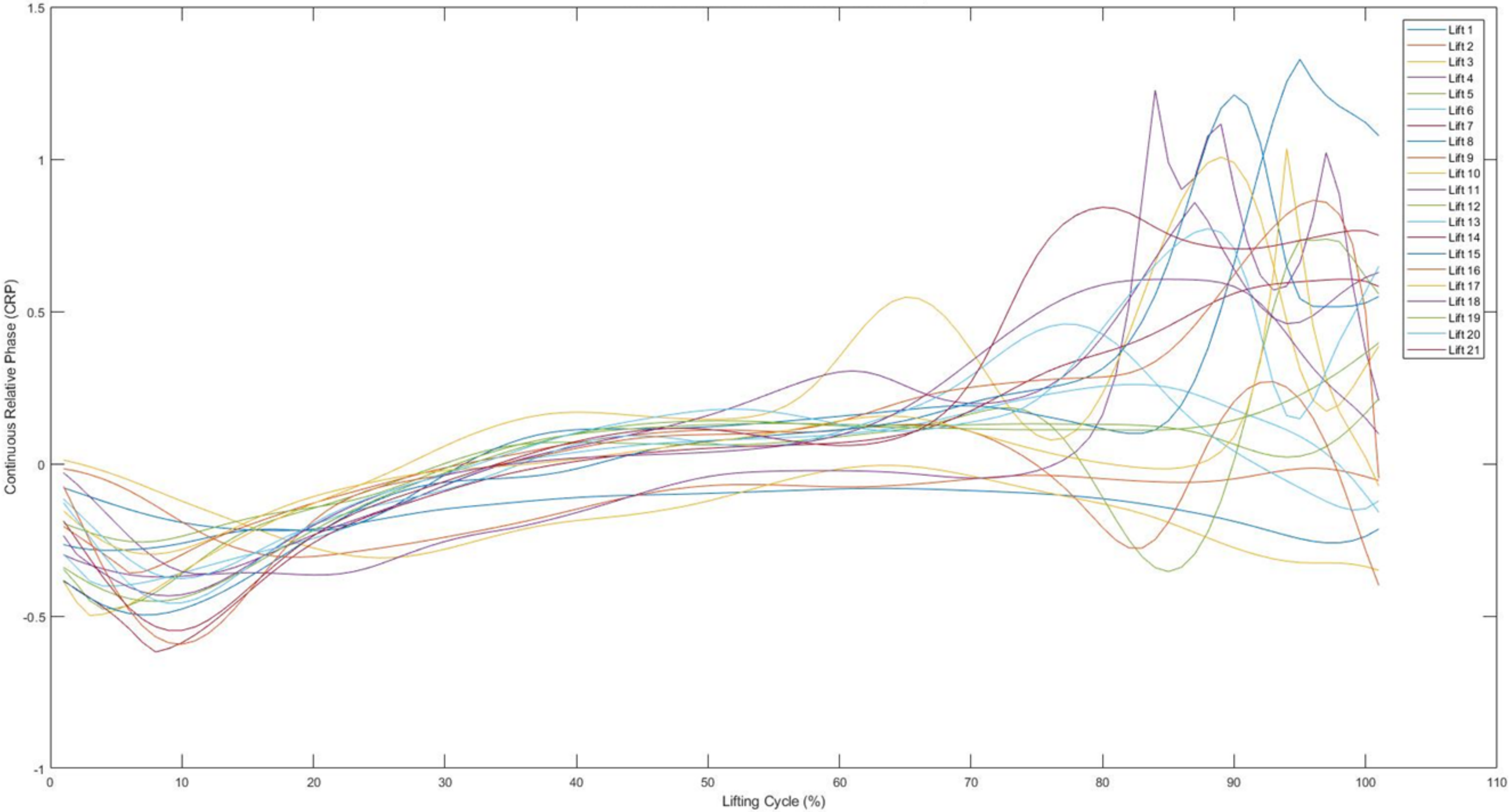

Figure 4.10: Continuous Relative Phase plot of Participant A for all 21 lifting cycles - Normalized.

4.5 Simplified Flowchart for Continuous Relative Phase Matlab Code

The concept of software design and development for CRP is illustrated in Figure 4.11. The final developed Matlab code is given in section B-2 of Appendix B.

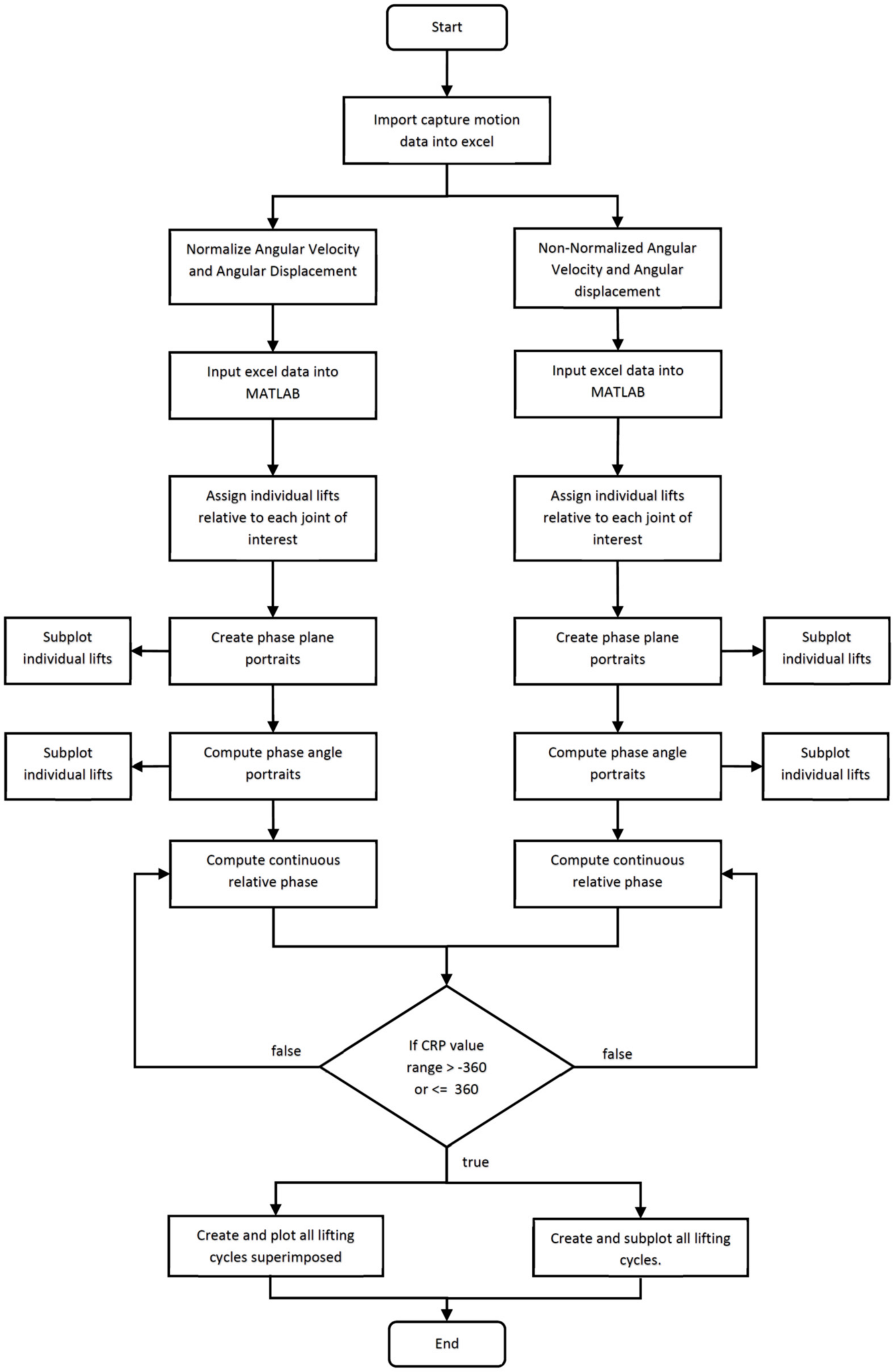

Figure 4.11: Matlab development flowchart for Continuous Relative Phase.

4.6 Interpretation of Continuous Relative Phase Results

Continuous Relative Phase is a measure, which describes the phase space relation between two segments (modelled as pendulum) as it evolves throughout the movement, which makes continuous relative phase an attractive and popular collective variable for inter and intra-limb coordination [34]. This is done by plotting the position signal of one joint versus the angular velocity of that joint in the phase-plane. The phase angle in this phase-plane is obtained, and the relative phase is the difference between the phasic angles of the two joints. CRP contains both continuous spatial and temporal information. As such it is considered a high-order form of DRP, as it includes higher-dimensional information through a more detailed analysis of the behaviour in state space, due to the inclusion of angular velocity in conjunction with the angular position of the joints of interest. Although this would prove valuable, what can be observed from the results of CRP, in which the angular position and angular velocity has been normalized, is that there is a significant loss of valuable temporal information when the normalizing process is computed.

This is obvious when assessing the results of CRP with DRP or the CRP results, in which, the angular position and angular velocity have not been normalized. DRP displayed a distinct phasic shift after the 4th lift which cannot be observed with the results from the normalized CRP. However, this shift is found in the non-normalized CRP results. In the non-normalized CRP results in this shift, where the knee extension starts to lead the hip extension, is seen when the graph transitions between the positive and negative or vice-versa, shown in Figure 4.12.

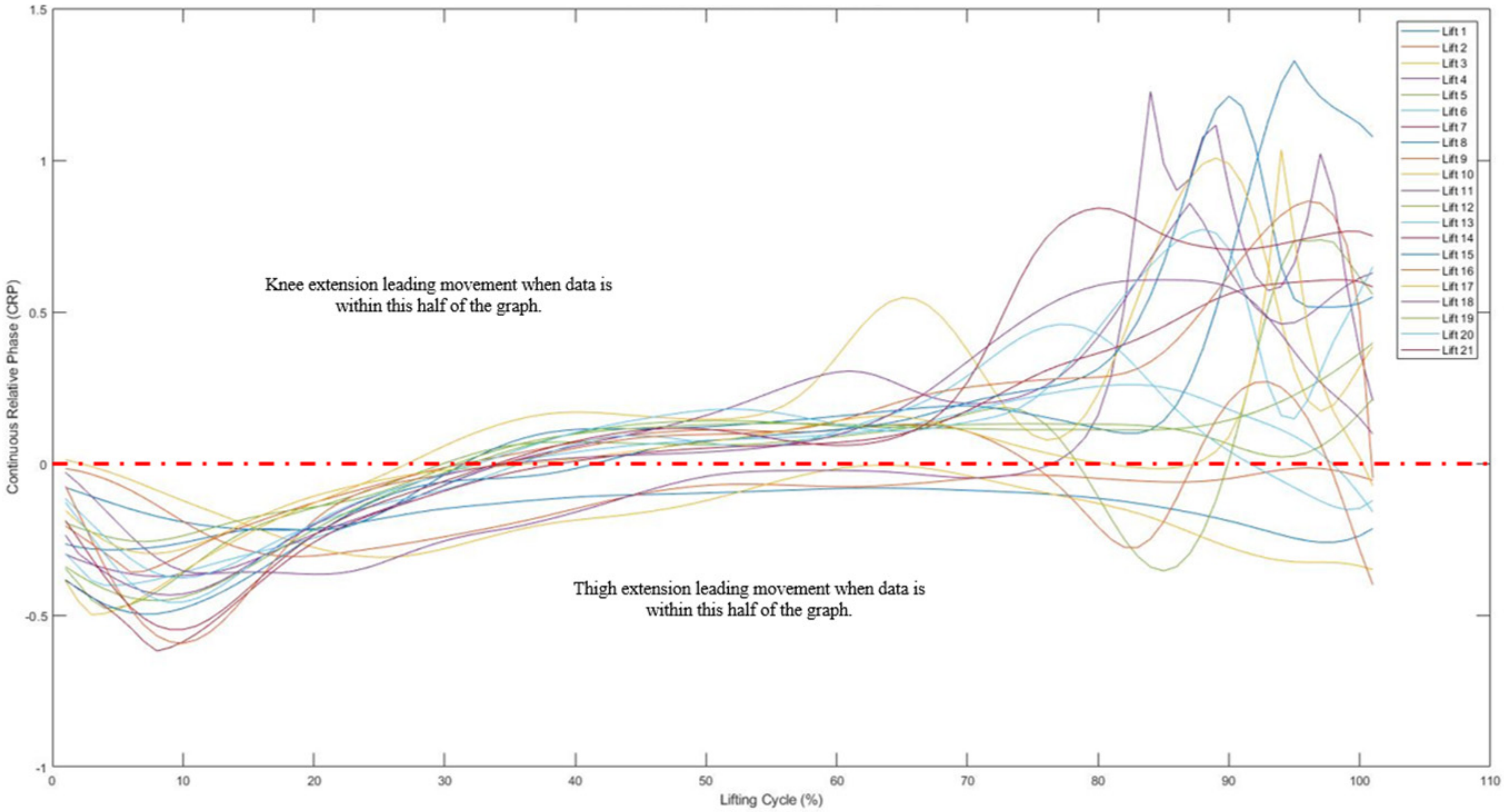

Figure 4.12: Simplified Interpretation of Continuous Relative Phase.

There are two main normalization methods which are used to scale data to the unit phase space, to control spurious oscillations when CRP is calculated [4, 14]. However, there have been other studies which have argued for no normalization in favour of maintaining the original topology or aspect ratio of the data [15, 16]. Peters and colleagues concluded that CRP results would be arbitrary if no normalization procedures are used to account for frequency differences in the component oscillator [17]. One study completed by Kurz and Stergiou in 2001 [16] indicated differences in the configuration of the non-normalized and normalized CRP curves through the use of root-mean-square (RMS) calculation [16]. The study also calculated CRP with a combination of two different amplitude normalization techniques and two different phase angle definitions. The differences between the methods were also noted with RMS calculation, with the study concluding that RMS values indicated profound differences in the CRP curve when the phase angle was normalized. And a phase angle was calculated relative to the right horizontal axis, but that normalization is not necessary because the arctangent function accounts for the differences in amplitudes between the segments. This is, in fact, correct when assessing the phase angle of the non-normalized data set in Figure 4.6, it can immediately be seen that the arctangent function has considered the differences in amplitudes between the segments.

In summary, when no normalization is conducted for the angular displacement and angular velocity, the results of CRP present accurate representation of the coordination of the joints of interest. The argument for normalizing also becomes redundant due to the final steps of CRP, where the arctangent function considers the magnitude differences between the angular displacement and velocity. CRP presented results which would enable the investigation of fatigue across a complete cycle and enable further analysis across multiple cycles.

Chapter 5
Vector Coding

This chapter covers the processes used for the analysis of biomechanical data sets of two joints of interest using vector coding procedure. The section includes the individual steps involved in the vector coding procedure and explains each step in the process. The chapter also examines the most recent development of vector coding, where the mean coupling angle is computed to enable the assessment of multiple gait cycles. Vector coding, along with DRP and CRP, has been used extensively in the evaluation of coordination and variability of two segments or joints. As stated in section 1.2, vector coding was first developed in 1987 by Sparrow et al. [20] after improvement to an earlier version called the *chain encoding* method [18]. Sparrow et al. recognized the difficulties in computationally superimposing unequally spaced data used in the encoded chain technique; Sparrow et al. proposed a revised equation given in equation (5.1), which considers the length of the frame-to-frame interval:

$$R_{xy}(j) = \frac{1}{N}\sum_{i=1}^{N} cos\left(\Theta_{x,i} - \Theta_{y,i+j}\right).\frac{|\bar{x}_i|}{|\bar{y}_{i+j}|} \quad j = 0,1 \ldots N-1 \qquad (5.1)$$

Provided $|\bar{x}_i| \leq |\bar{y}_{i+j}|$, $\Theta_{x,i}$ and $\Theta_{y,i+j}$ are angles between adjacent points, $|\bar{x}_i|$ and $|\bar{y}_{i+j}|$ are lengths of the frame-to-frame intervals, and N is the number of frame-to-frame intervals in two chains. R_{xy} is the cross-correlation function. The method developed by Sparrow et al. and later used by Tepavac and Field-Fote [21] to quantify the similarity or variability in angle-angle diagrams is outlined in this chapter.

5.1 Relative Phase Plot

Relative phase plots are known as angle-angle diagrams, which provide information on the angle of two joints of interest, plotted against each other throughout a gait cycle [35, 36]. This research used the two joints of interest, which are the hip and knee. The gait cycle, in our case, is defined as the initial position of the lifting task to the completion of the lifting task. The relative phase plots of participant A are shown in Figure 5.1.

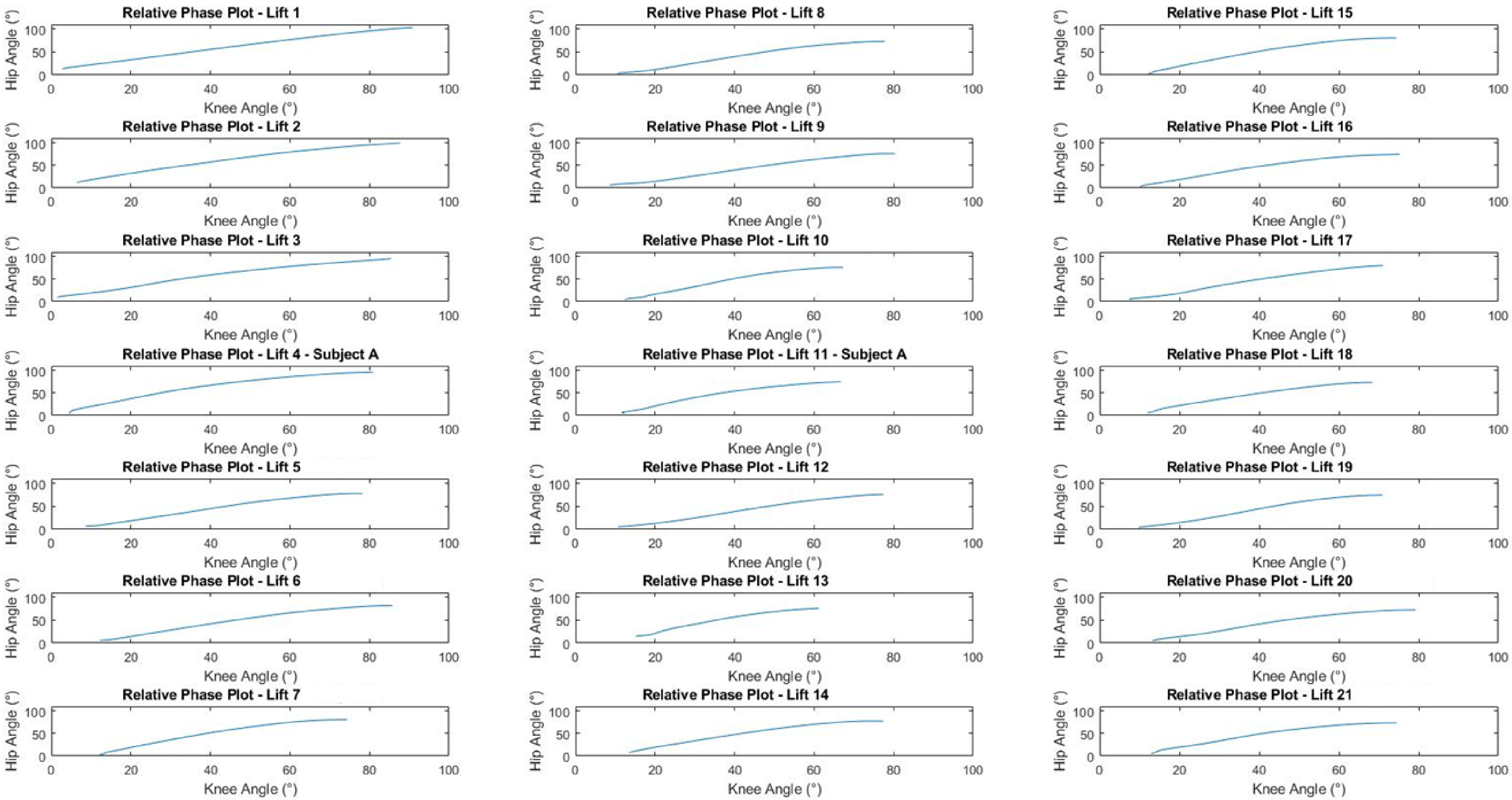

Figure 5.1: Relative Phase subplots for Participant A.

5.2 Coupling Angle of Individual Lifts

The orientation of the vector between two adjacent points on the angle-angle plot relative to the right horizontal is the coupling angle [37]. Equation (5.2) is used to calculate the coupling angle.

$$\gamma_{j,i} = tan^{-1}\left(\frac{y_{j,i+1} - y_{j,i}}{x_{j,i+1} - x_{j,i}}\right) \tag{5.2}$$

where, $\gamma_{j,i}$ is the coupling angle at a fraction of the gait cycle. $y_{j,i}$ is the hip angle at a fraction of the gait cycle. $y_{j,i+1}$ is the hip angle at the following fraction of the gait cycle. $x_{j,i}$ is the knee angle at a fraction of the gait cycle, and $x_{j,i+1}$ is the knee angle at the following fraction of the gait cycle.

The results for the coupling angle shown in Figure 5.2 for participant A across all 21 lifts.

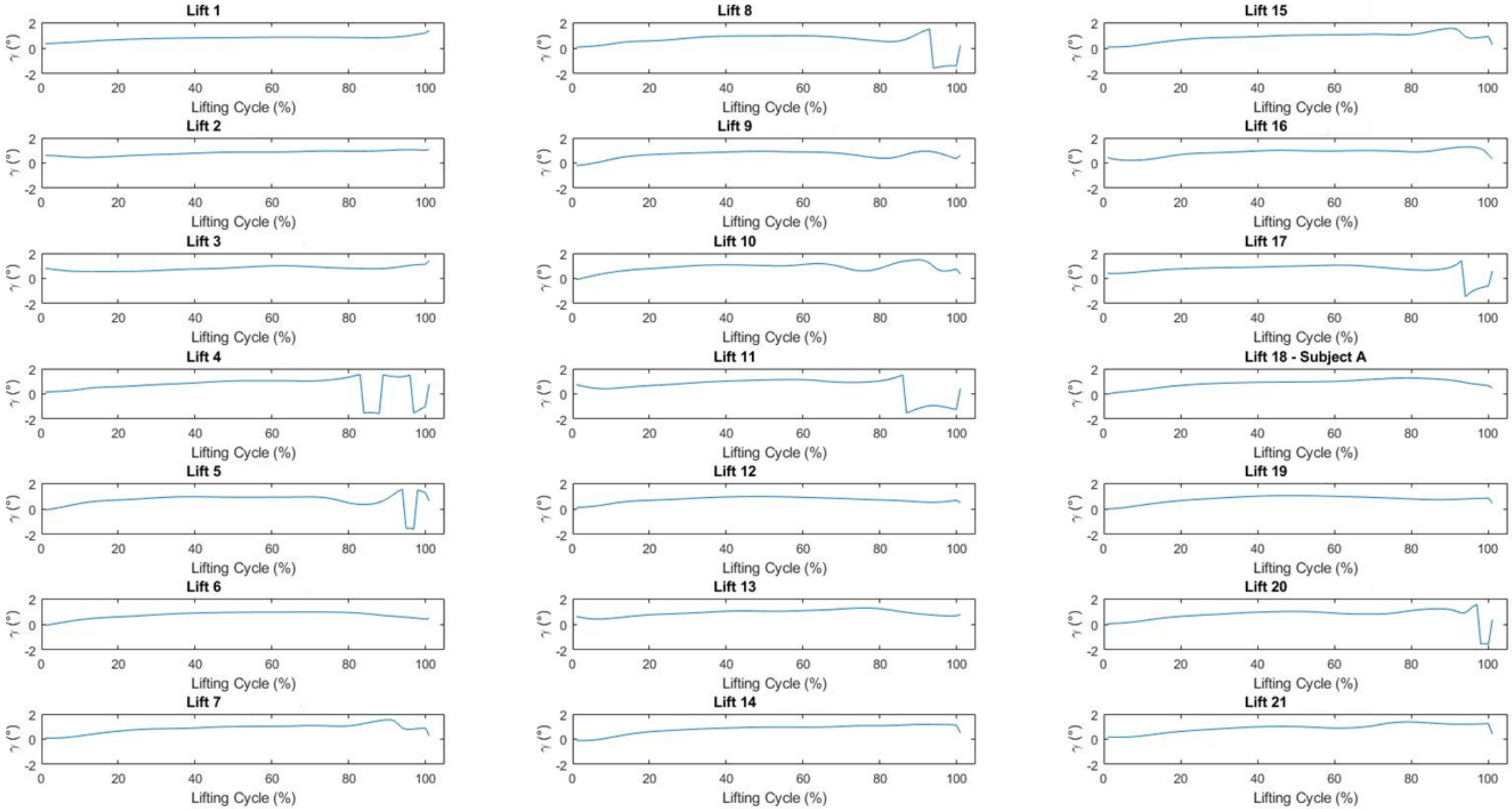

Figure 5.2: Coupling Angle subplots of Participant A for all 21 lifting cycles.

5.3 Mean Coupling Angle

An addition to the previous methods of Vector Coding is the calculation of a mean coupling angle (CA) within a participant and then across a group if applicable, using circular statistics [35, 38, 39]. Equations (5.3) and (5.4) address how the mean coupling angle is calculated.

$$\bar{x}_i = \frac{1}{n}\sum_{j=1}^{n}(cos\,\gamma_{j,i}) \tag{5.3}$$

where, $\bar{x}_i$ is the mean horizontal component at the cycle percentage i, and j represents the lifting cycle.

$$\bar{y}_i = \frac{1}{n}\sum_{j=1}^{n}(sin\,\gamma_{j,i}) \tag{5.4}$$

where, $\bar{y}_i$ is the mean vertical component at the cycle percentage i, and j represents the lifting cycle. In this experiment, the mean horizontal component $\bar{x}_i$ remained above 0, this meant that equation (5.5) would be applied to compute the mean coupling angle $\bar{\gamma}_i$ for participant A.

$$\bar{\gamma}_i = tan^{-1}\left(\frac{\bar{y}_i}{\bar{x}_i}\right) \tag{5.5}$$

The mean coupling angle for participant A is shown in Figure 5.3.

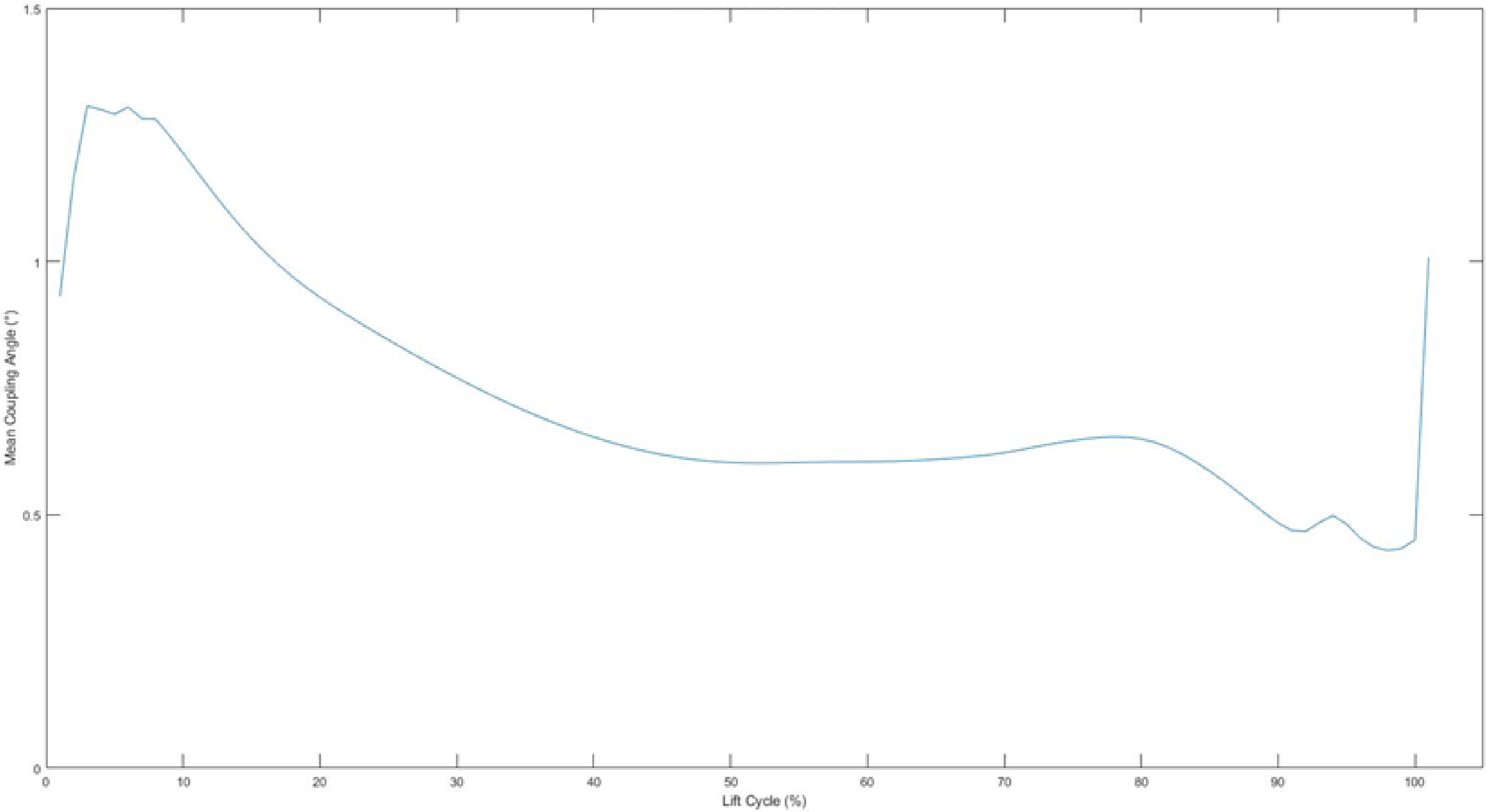

Figure 5.3: Mean Coupling Angle of Participant A.

5.4 Simplified Flowchart for Vector Coding Matlab Code

The concept of the software design and development for Vector Coding is illustrated in Figure 5.4. The final developed Matlab code is given in section B-3 of Appendix B.

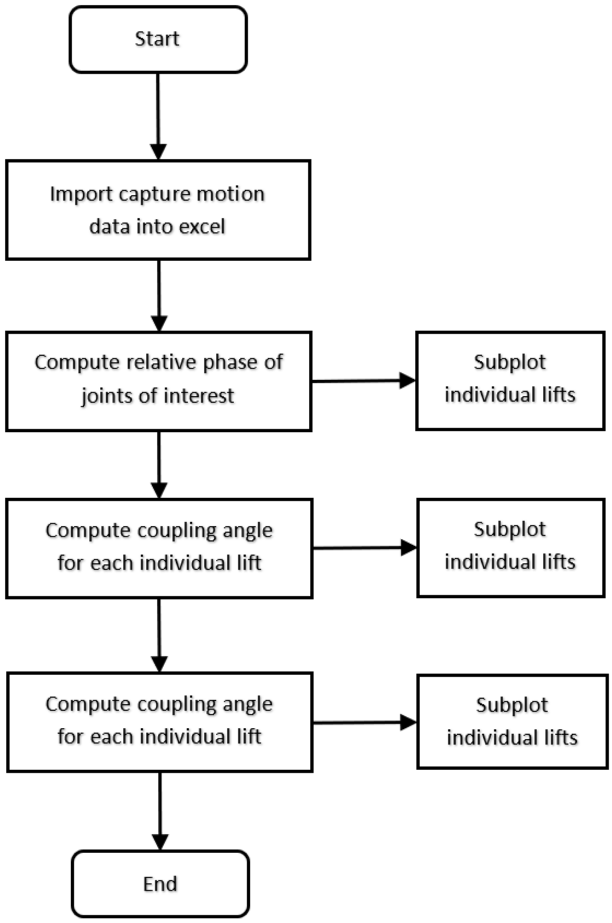

Figure 5.4: Matlab development flowchart for Vector Coding

5.5 Interpretation of Vector Coding

The output of the results from vector coding are not the joint angles, but the direction and magnitudes of the frame to frame vectors. Vector coding employs a similar technique which uses the arctangent function to assess the space plane of the two joints of interest. While CRP employs the arctangent function on the individual joints, considering the angular displacement as well as the angular velocity, vector coding employs the arctangent on both joints without assessing the angular velocity of the single joints themselves and applies the arctangent function for the difference between two percentage stances of each joint. The arctangent function in vector coding is used to establish the coupling angle which is defined as the difference of each joint angle between percentage cycles, $(\theta_{hip}, \theta_{knee})$. This coupling angle, therefore, only describes the difference between two percentage stances during the gate cycle. The mean coupling angle combined all twenty-one lifts, which would make this technique redundant for the assessment of fatigue due to the inability to assess joint coordination over the multiple movement cycles.

In summary, the method and equations used in the analysis of biomechanical data sets using the vector coding procedure have been outlined in this chapter. Vector coding does provide information regarding the joint coordination of two joints of interest. However, this information is limited to the direction and magnitudes of the frame to frame vectors over a complete gait cycle and therefore does not provide valuable information relating to the assessment of fatigue over a full cycle.

Chapter 6
Principal Component Analysis

This chapter covers the method and equations used in the use of Principal Component Analysis (PCA) of biomechanical data sets. This chapter emphasises the use of the correlation matrix within the steps used for the analysis using PCA. The interpretation and merits of PCA are also discussed, as well as future work for a thorough and complete evaluation of the use of PCA in the analysis of biomechanical data sets. The information obtained from the coordination analysis techniques discussed in chapters 3 to 5 does provide valuable information. When wanting to assess fatigue, there are issues in how the data is displayed and interpreted. The previous chapters explain how the techniques are commonly understood and presented. The standard techniques also pose limitations when one is trying to compare the results between participants and/or groups. This limitation is due to the nature of the data. The biomechanical data is rather large; for example, in this research, we are assessing one participant across 21 lifting cycles. Each of the 21 lifting cycles is represented at each percentage of the lifting cycle (from 0% to 100%). Therefore there are a total of $21 \times 101 = 2{,}121$ data points for only one participant. The raw data to be analysed can also be viewed in appendix A.

Often within biomechanics, it usual to compare results of more than 100 participants. This would mean that there would be $100 \times 21 \times 101 = 212{,}100$ data points, and it is for this reason, that the data is described as multidimensional. This is where the issue of interpretation and displaying via the standard methods arises, mainly if the research topic is concerned with assessing fatigue across several cycles. These limitations, however, can be addressed from the use of Principal Component Analysis (PCA) as outlined within this chapter. PCA is a technique which is unique to the multivariate arena, PCA is often employed as data-analytic techniques that seek to describe the multidimensional structure of the data. PCA in simple terms is an orthogonal decomposition technique, meaning that the resulting principal components (PC) are independent of each other.

PCA is a mathematical algorithm that seeks to find a small set of orthogonal variables to capture the variation in the original variables [35, 40]. More specifically, orthogonal transformation converts several correlated variables into a smaller number of uncorrelated, independent variables [35]. These independent variables are called principal components. PCA has been used extensively within studies of biomechanics, including assessing balance [41], assessing differences between normal and abnormal gait [42, 43], and surface electromyography [25, 44-46]. The following calculation process for PCA has been sourced from two books, the first book *'A User's Guide to Principal Components'* is a general user guide to PCA [47] and the second book *'Research Methods in Biomechanics'* explains PCA from a biomechanical analysis perspective [35].

6.1 Vector Matrix

Creating a sample vector matrix is the first step in the calculation process of PCA. For this research, we are assessing only one participant across the 21 cycles. Equation (6.1) displays the sample matrix for this research.

$$X = \begin{bmatrix} X_1 & X_2 & \cdots & X_{100} & X_{101} \\ X_2 & X_3 & \cdots & X_{101} & X_{102} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ X_{21} & X_{22} & \dots & X_{120} & X_{121} \end{bmatrix} \tag{6.1}$$

where X represents the sample matrix, each row represents the different lifting cycles 1 to 21, and the columns represent the values at each fraction of the lifting cycle. This experiment assesses 21 lifting cycles which can be seen in the first column which has a range of between X_1 and X_{21}. Each of the rows indicates the percentage cycle which can be seen to be between X_1 and X_{101}.

6.2 Covariance Matrix

The covariance matrix is the first step for the calculation of PCA when calculating variables which have the same measured units. The covariance matrix is used when, for example, assessing the joint angles across several participants. When one is determining the angular position among the angular velocity, then one must instead use the correlation matrix.

The interest is in the variation in this data set. This includes how the waveforms change over the lifting cycle period and how each lifting cycle varies from another. To express the variance structure within dataset the covariance matrix of the columns of X is used, here signified as S. Equation (6.2) displays the covariance structure S as:

$$S = \begin{bmatrix} S_i^2 & S_2 & \cdots & S_{100} & S_{101} \\ S_2 & S_3^2 & \cdots & S_{101} & S_{102} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ S_{21} & S_{22} & \ldots & S_{120} & S_{121}^2 \end{bmatrix} \tag{6.2}$$

where, S_1^2 is the variance of the i^{th} variable (difference at each instance of the waveform), x_1, and s_{ij} is the covariance between the i^{th} and j^{th} variables (covariance between each pair of time instances).

$$S_i^2 = \frac{\sum_{k=1}^{n}(x_{ki} - \bar{x}_i)^2}{n - 1} \tag{6.3}$$

where i is the column and n is the number of rows of the lifting cycles.

S_{ij} represents the covariance between each pair of time series, given as:

$$S_{ij} = \frac{\sum_{k=1}^{n}(x_{ki} - \bar{x}_i)(x_{kj} - \bar{x}_j)}{n - 1} \tag{6.4}$$

where i and j are two of the columns and n is the number of rows (lifting cycles). If the covariances are not equal to zero, it indicates that a linear relationship exists between these two variables. The strength of that relationship is represented by the correlation coefficient, given by:

$$r_{ij} = \frac{S_{ij}}{(S_i S_j)} \tag{6.5}$$

6.3 Correlation Matrix

The correlation matrix is shown in both equation (6.5) and (6.6) represent the alternative method of using the covariance matrix. It can also serve the strength of that relationship between the variables assessed.

$$r_{ij} = \frac{Cov(i,j)}{(S_i S_j)} \tag{6.6}$$

6.4 Orthogonal Decomposition

A transformation from the original data covariance matrix S to the principal components covariance L is known as orthogonal decomposition or as diagonalization. A $p \times p$ symmetric, non-singular matrix, such as the covariance matrix S, may be reduced to a diagonal matrix L by pre-multiplying and post-multiplying it by an orthonormal array U such that:

$$U'SU = L \tag{6.7}$$

This will transform p correlated variables $x_1, x_2, \dots \dots, x_p$ into p new uncorrelated variables $z_1, z_2, \dots \dots, z_p$. The coordinate axes of these new variables are described by the characteristic vectors u_i which make up the matrix U of direction cosines used in the transformation:

$$z = U'[x - \bar{x}] \tag{6.8}$$

where x and $\bar{x}$ are $p \times 1$ vectors of observations on the original variables and their means. The transformed variables are called principal components (PC). The i^{th} PC is:

$$z_i = u_i'[x - \bar{x}] \tag{6.9}$$

There is a need to distinguish between transformed variables (PC) and the individual transformed observations. The individual changed observations are called z-scores. The z-scores account for the variance of the original variables. The transformed variables are used to create the scree plot to which one can understand the weight each transformed variables carries; the scree plot shown in Figure 6.1.

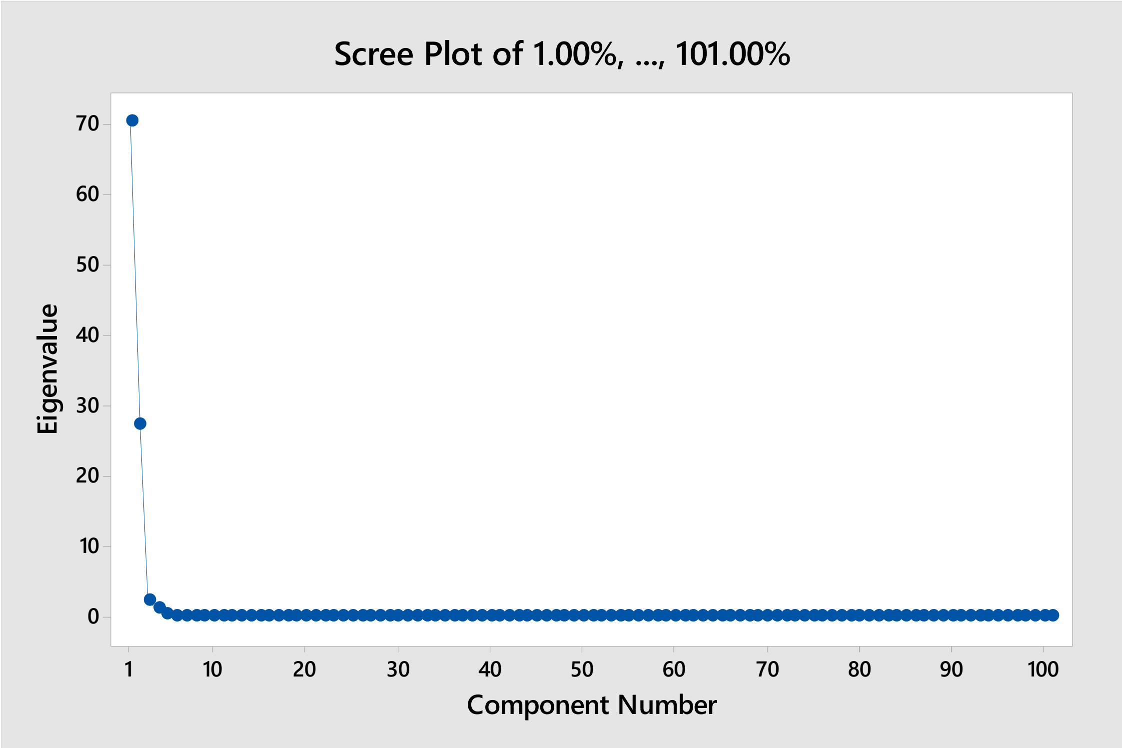

Figure 6.1: Scree Plot outlining the dominant Principal Components – Correlation Matrix.

6.5 Principal Component Analysis Results

A principal component analysis using correlation matrix was conducted on the angular displacement of Participant A's knee and hip joint angles. The scree plot, shown in Figure 6.1, shows that the first two principal components account for 98% of the variation. The score plot displays, shown in Figure 6.2, these two principal components and displays results which are consistent with the results gathered from both DRP and CRP.

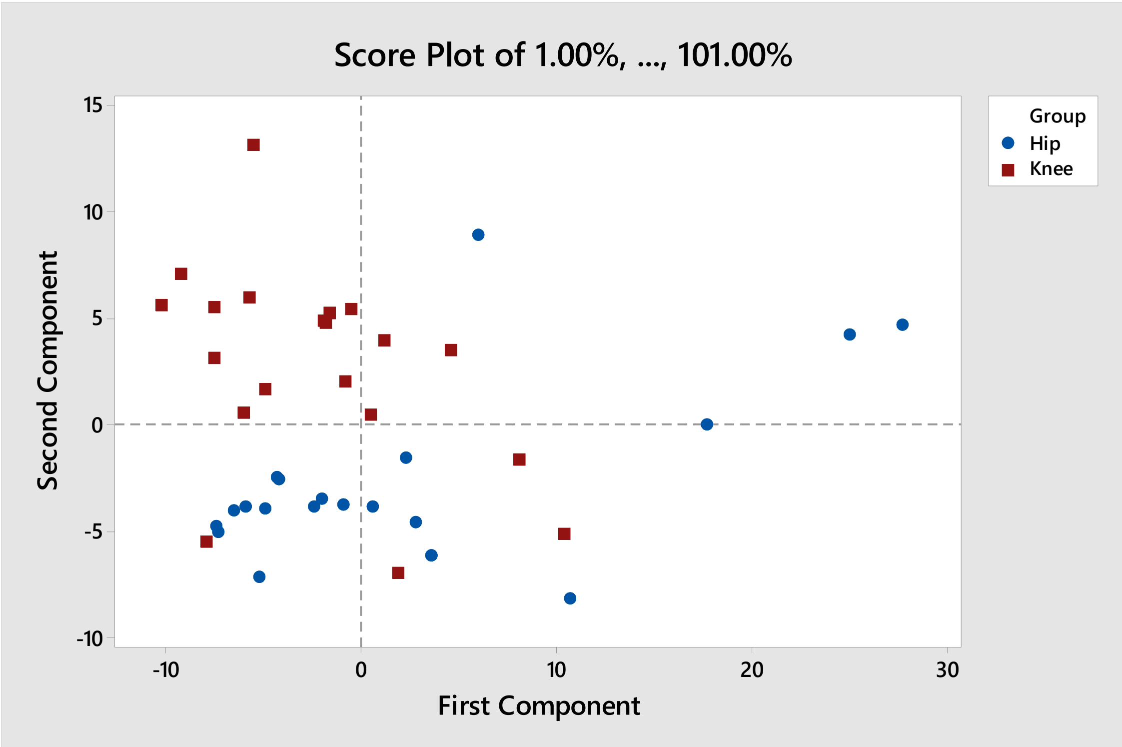

Figure 6.2: Score plot outing the dominant principal components.

6.6 Simplified Flowchart for Principal Component Analysis

The concept of software design and development using Minitab software for PCA is illustrated in Figure 6.3.

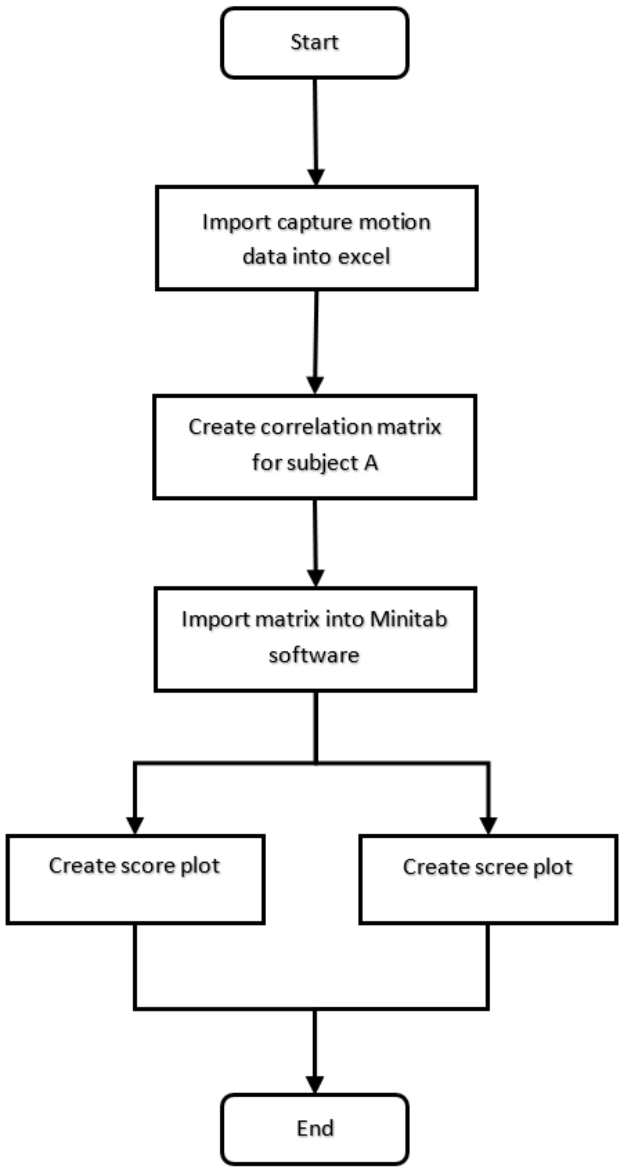

Figure 6.3: Minitab development flowchart for Principal Component Analysis.

6.7 Interpretation of Principal Component Analysis Results.

The interpretation of PCA can prove quite difficult depending on which matrix is used, how many participants are assessed, the number of joints assessed, and whether only joint angles are assessed or if the angular velocity of the joints is also assessed. These factors are taken into consideration, and a scree plot must be provided to provide the number of principal components which account for the largest variation of the data set. When the number of principal components is found, these will need to be analysed to find the variation each represents.

In the above example, the correlation matrix was employed, on one participant, assessing only the knee and hip joint angular displacement. The result of these is that there are two principal components, which account for approximately 85-90% of the variation. This would mean that only the first two components are required to address the variation in the complete data sets. The score plot displayed in Figure 6.2 displays the two PC's plotted against each other. With this assessment using the above variables, we do see a pattern associated with what was displayed with CRP and DRP.

In summary, this chapter details the method and equations used in the analysis of biomechanical data sets using a correlation matrix on the angles of two joints of interest on one participant. PCA displays promising information relating to the assessment of fatigue in multicyclic movements. PCA displays information which is consistent with the use of both DRP and CRP. PCA does merit further investigation, which would constitute a comparative study between the use of the correlation matrix and covariance matrix. The comparison of these matrices in the computation of PCA would enable a thorough investigation into the use of PCA for not only joint angles of interest but also the assessment of joint angular velocity conjunction with the angular displacement of each of the joints of interest.

Chapter 7
Discussion and Conclusion

In conclusion, the mathematical analysis techniques discussed within this research presented adequate results for inter-joint coordination of the lower extremities. Both Discrete Relative Phase and Continuous Relative Phase provided information which may be used for the assessment of fatigue, with Continuous Relative Phase providing a high-order representation of the coordination. Vector coding provided information relating to the inter-joint coordination of the lower extremities. However, due to the results displaying the direction and magnitude of the frame to frame vectors, this meant that the overall coordination throughout a given cycle could not be adequately assessed based on only a vector coding assessment to assess fatigue. The principal component analysis provided a promising assessment of biomechanical data sets, both in the dimensionality reduction and interpretation of the data. Due to the many variables and combinations which may be used when the principal component analysis is applied to biomechanical data sets, it warrants further research. Two differing matrices' can be applied to a principal component analysis, with the ability to assess the angular velocity and angular displacement in conjunction with each other, with the use of the correlation matrix which discards the differences between the units. The use of the covariance matrix can be used for the assessment of only angular displacement of two or more joints or segments of interest. Efforts can be made to further assess the corresponding principal components from the outputted matrix results to further analyses the results, and further techniques such as a cluster analysis can be applied to cement the findings. The findings can then be scaled for the assessment of multiple participants and/or groups of participants.

Appendix A

Section A-1	Knee Angular Displacement Data for Participant A.
Section A-2	Hip Angular Displacement Data for Participant A
Section A-3	Knee Angular Velocity Data for Participant A
Section A-4	Hip Angular Velocity for Participant A

Section A-1 Knee Angular Displacement Data for Participant A

	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee	Knee
	Lift 1	Lift 2	Lift 3	Lift 4	Lift 5	Lift 6	Lift 7	Lift 8	Lift 9	Lift 10	Lift 11	Lift 12	Lift 13	Lift 14	Lift 15	Lift 16	Lift 17	Lift 18	Lift 19	Lift 20	Lift 21
1	90.84765	87.65907	85.39964	80.82765	78.25189	85.6832	74.42027	77.75821	80.31627	67.26551	66.72262	77.3812	61.20958	77.42387	74.42027	75.21993	71.06688	68.41312	70.91638	79.24934	74.50402
2	90.68521	87.54258	85.26508	80.32641	77.81938	85.32581	74.00756	77.43465	79.97752	66.8137	66.54044	77.197	61.01247	77.04629	74.00756	75.0292	70.83401	68.20632	70.65812	79.05451	74.25207
3	90.4981	87.40099	85.11087	79.79417	77.34714	84.94019	73.55864	77.0905	79.61514	66.31336	66.31342	76.98675	60.77661	76.64302	73.55864	74.74407	70.54842	67.95358	70.37194	78.78728	73.93156
4	90.28646	87.23171	84.9358	79.2345	76.83545	84.52704	73.07626	76.72759	79.23189	65.76672	66.03881	76.75043	60.50105	76.21426	73.07626	74.36096	70.21173	67.65478	70.05727	78.44324	73.5387
5	90.04977	87.03218	84.73811	78.65025	76.28563	84.08723	72.56316	76.34869	78.83052	65.17744	65.71548	76.48821	60.18527	75.75996	72.56316	73.87881	69.82655	67.31079	69.71362	78.02004	73.07082
6	89.78223	86.7998	84.51538	78.04387	75.69967	83.62129	72.02174	75.95702	78.41291	64.54982	65.3435	76.20029	59.82916	75.27988	72.02174	73.29934	69.39649	66.92336	69.34039	77.51767	72.52689
7	89.48598	86.53249	84.26469	77.41725	75.07948	83.12917	71.45386	75.55502	77.97976	63.88826	64.92356	75.8867	59.43296	74.77357	71.45386	72.62681	68.92562	66.4948	68.93694	76.93836	71.9078
8	89.16529	86.22872	83.98252	76.771	74.42599	82.6104	70.86069	75.14352	77.53049	63.19686	64.45628	75.5471	58.99737	74.24025	70.86069	71.86789	68.41833	66.02805	68.50265	76.28641	71.216
9	88.81638	85.88729	83.66517	76.10352	73.73863	82.06439	70.24306	74.72096	77.06361	62.47946	63.94164	75.18069	58.5239	73.67928	70.24306	71.03178	67.87851	65.52617	68.03709	75.56735	70.45512
10	88.43911	85.50713	83.30875	75.41091	73.0155	81.49046	69.60192	74.28344	76.57732	61.7393	63.37846	74.78604	58.01479	73.09031	69.60192	70.12947	67.30956	64.99226	67.54038	74.78696	69.62938
11	88.03439	85.08756	82.90939	74.68773	72.25374	80.88779	68.93851	73.82478	76.06926	60.97857	62.76475	74.36115	57.47298	72.47347	68.93851	69.17311	66.71424	64.42915	67.01326	73.9508	68.74318
12	87.60096	84.62806	82.46341	73.9278	71.45022	80.25549	68.25436	73.33647	75.53639	60.19788	62.09831	73.90353	56.90208	71.82951	68.25436	68.17492	66.09473	63.8389	66.45718	73.06403	67.80112
13	87.13792	84.12794	81.96685	73.12506	70.60195	79.59213	67.55072	72.80886	74.97517	59.39633	61.3776	73.41049	56.30581	71.15961	67.55072	67.14596	65.45258	63.22286	65.87424	72.13123	66.80834
14	86.64435	83.58737	81.41563	72.27411	69.7063	78.89602	66.82868	72.23256	74.38202	58.57185	60.60223	72.87939	55.68779	70.46522	66.82868	66.09572	64.7885	62.58135	65.26686	71.15675	65.77093
15	86.11896	83.00694	80.80573	71.3709	68.76093	78.16507	66.08942	71.60033	73.75391	57.72142	59.77303	72.3078	55.05134	69.74783	66.08942	65.03172	64.10255	61.91399	64.63756	70.14437	64.69585
16	85.5604	82.38762	80.13353	70.41348	67.76456	77.39674	65.33481	70.90834	73.08845	56.84202	58.89185	71.69382	54.39938	69.00882	65.33481	63.95975	63.39433	61.21982	63.98864	69.09756	63.59024
17	84.96741	81.7309	79.39671	69.40137	66.71732	76.58865	64.56749	70.15665	72.38407	55.93151	57.96098	71.03625	53.73438	68.24932	64.56749	62.88393	62.66316	60.49749	63.32206	68.01979	62.46058
18	84.33891	81.03838	78.59476	68.33527	65.62081	75.73901	63.79064	69.3488	71.64063	54.98933	56.98262	70.33468	53.05837	67.47022	63.79064	61.80636	61.90839	59.74567	62.63924	66.91441	61.31201
19	83.67373	80.31139	77.7293	67.21632	64.47791	74.84697	63.00773	68.49049	70.8589	54.01687	55.95857	69.58966	52.37272	66.67215	63.00773	60.72704	61.12945	58.96316	61.94119	65.78472	60.14832
20	82.97084	79.55079	76.804	66.04578	63.29215	73.91341	62.22224	67.58853	70.04021	53.01736	54.89054	68.80254	51.67801	65.85569	62.22224	59.64401	60.32613	58.14923	61.22838	64.63394	58.97246
21	82.2295	78.75662	75.82404	64.82527	62.06749	72.94064	61.43733	66.64973	69.18584	51.99553	53.78078	67.97532	50.97412	65.02142	61.43733	58.55363	59.49861	57.30357	60.50093	63.46523	57.78691
22	81.44965	77.92861	74.79538	63.55718	60.80854	71.93218	60.65549	65.67979	68.29706	50.95719	52.63272	67.11043	50.26036	64.16989	60.65549	57.45129	58.6474	56.42637	59.75861	62.28171	56.59423
23	80.63194	77.06664	73.72392	62.24569	59.52089	70.89243	59.87846	64.68282	67.37543	49.90899	51.4512	66.21057	49.53606	63.30183	59.87846	56.33197	57.77333	55.51833	59.00113	61.08651	55.39744
24	79.77785	76.17139	72.61458	60.89741	58.21137	69.8263	59.10719	63.66172	66.42287	48.85816	50.24223	65.27843	48.80073	62.41814	59.10719	55.19087	56.87742	54.58054	58.22824	59.88284	54.20029
25	78.8896	75.24411	71.47124	59.52069	56.8876	68.73898	58.34174	62.61904	65.44165	47.8119	49.01226	64.31634	48.05449	61.51993	58.34174	54.02399	55.96081	53.61429	57.43985	58.67432	53.00722
26	77.96978	74.28648	70.29729	58.12425	55.55721	67.63557	57.5814	61.55797	64.43446	46.77682	47.76801	63.32606	47.29802	60.60837	57.5814	52.8285	55.02487	52.6208	56.63615	57.46494	51.82325
27	77.021	73.30042	69.09608	56.71576	54.22706	66.5205	56.82485	60.48285	63.40459	45.75822	46.51608	62.30914	46.53274	59.68465	56.82485	51.60344	54.07121	51.60097	55.81773	56.2583	50.65294
28	76.04569	72.2877	67.87119	55.3009	52.90279	65.39723	56.07038	59.39951	62.35572	44.7595	45.26265	61.26735	45.76079	58.74962	56.07038	50.34966	53.10171	50.55511	54.98569	55.05681	49.49957
29	75.04595	71.24997	66.62636	53.88343	51.58884	64.26804	55.31601	58.31441	61.29163	43.78206	44.0134	60.20328	44.98505	57.80362	55.31601	49.06973	52.11866	49.4837	54.14158	53.86193	48.36485
30	74.02354	70.18864	65.36512	52.46601	50.28873	63.13428	54.55946	57.23357	60.21593	42.82593	42.77322	59.12022	44.20903	56.84641	54.55946	47.76798	51.1246	48.38789	53.28759	52.67504	47.2496
31	72.98009	69.10488	64.09064	51.05076	49.0054	61.99668	53.79814	56.16153	59.13078	41.89023	41.5461	58.02203	43.43677	55.87715	53.79814	46.44997	50.12244	47.27039	52.42635	51.49826	46.15466
32	71.91682	67.99985	62.80579	49.63924	47.74121	60.85543	53.02917	55.10079	58.03633	40.97366	40.33513	56.9124	42.67245	54.89468	53.02917	45.12213	49.11542	46.13491	51.56085	50.33455	45.08097
33	70.83456	66.87483	61.51297	48.23265	46.49798	59.71045	52.24959	54.0519	56.93112	40.07483	39.14252	55.79456	41.92009	53.89757	52.24959	43.79142	48.10698	44.98587	50.69396	49.18743	44.0293
34	69.73378	65.73145	60.21362	46.83179	45.27665	58.56174	51.45638	53.01381	55.81342	39.19243	37.96992	54.67117	41.18331	52.88441	51.45638	42.46478	47.10067	43.82755	49.8281	48.06028	42.99997
35	68.61488	64.57163	58.90792	45.43743	44.07717	57.40963	50.6465	51.98402	54.68251	38.32507	36.81882	53.54432	40.46486	51.85398	50.6465	41.14894	46.0997	42.66395	48.96471	46.95583	41.99295
36	67.47862	63.39769	57.59482	44.0508	42.89834	56.25482	49.81717	50.95875	53.53927	37.47083	35.69079	52.41576	39.76654	50.80546	49.81717	39.85014	45.10677	41.4987	48.10452	45.87586	41.00802
37	66.32627	62.21206	56.27231	42.67397	41.7381	55.09796	48.96617	49.93329	52.38581	36.62698	34.58747	51.28702	39.08887	49.73864	48.96617	38.57399	44.12386	40.33514	47.24759	44.82122	40.04482
38	65.15955	61.01731	54.93802	41.30972	40.594	53.93941	48.09206	48.90272	51.22466	35.78996	33.51055	50.15947	38.43119	48.65385	48.09206	37.32537	43.15206	39.17643	46.39377	43.79207	39.10287
39	63.98052	59.81601	53.58942	39.96093	39.46384	52.7791	47.19404	47.86293	50.05799	34.95569	32.46153	49.03434	37.79193	47.55214	47.19404	36.10829	42.1918	38.02539	45.54281	42.78812	38.18169
40	62.79142	58.61055	52.22394	38.63078	38.34622	51.61702	46.27184	46.81131	48.88712	34.12011	31.4416	47.9129	37.16885	46.43509	46.27184	34.92574	41.24284	36.88461	44.69449	41.80879	37.28064
41	61.59433	57.40305	50.84003	37.32285	37.24075	50.45345	45.32576	45.74712	47.71236	33.27964	30.45143	46.79659	36.55958	45.30479	45.32576	33.77968	40.30475	35.75641	43.84867	40.85317	36.39891

42	60.39095	56.1952	49.43899	36.04138	36.14788	49.28913	44.35673	44.6714	46.53349	32.43142	29.49132	45.68711	35.96169	44.16381	44.35673	32.67069	39.37704	34.64288	43.00538	39.91992	35.53554
43	59.18231	54.98824	48.02601	34.79072	35.06868	48.12489	43.3664	43.58659	45.35049	31.57341	28.56168	44.58627	35.37276	43.01493	43.3664	31.59784	38.45952	33.54579	42.16481	39.0073	34.68932
44	57.96881	53.78297	46.60841	33.57444	34.00449	46.96143	42.35723	42.49605	44.16439	30.70446	27.66346	43.49586	34.79037	41.86108	42.35723	30.55899	37.55233	32.46658	41.32737	38.11321	33.85877
45	56.75032	52.57984	45.1935	32.39423	32.95664	45.79921	41.33244	41.40341	42.97758	29.82467	26.79804	42.41734	34.21225	40.70516	41.33244	29.55113	36.65591	31.40645	40.49363	37.23549	33.04217
46	55.52658	51.3787	43.78783	31.24965	31.92624	44.63862	40.29578	40.31206	41.79358	28.93569	25.96686	41.35184	33.63641	39.55004	40.29578	28.57139	35.77089	30.36662	39.66426	36.37234	32.23734
47	54.29739	50.17908	42.39762	30.13882	30.91411	43.48016	39.25128	39.22469	40.61618	28.04078	25.1713	40.30004	33.06128	38.39846	39.25128	27.61751	34.89793	29.34835	38.83992	35.5224	31.44172
48	53.06281	48.98029	41.02893	29.05913	29.92075	42.32439	38.20297	38.14303	39.44873	27.14456	24.41258	39.26214	32.48574	37.253	38.20297	26.68838	34.03767	28.35304	38.0212	34.68447	30.65247
49	51.82307	47.78158	39.68726	28.00766	28.94658	41.1719	37.15479	37.0678	38.29386	26.25288	23.69186	38.23811	31.90906	36.1161	37.15479	25.7841	33.19061	27.38226	37.20854	33.85728	29.8666
50	50.57853	46.58219	38.37719	26.98125	27.99206	40.02335	36.11045	35.99897	37.15324	25.37272	23.01024	37.22786	31.33083	34.99004	36.11045	24.90575	32.35722	26.4377	36.4021	33.03933	29.08118
51	49.32961	45.38114	37.10211	25.97635	27.05776	38.87957	35.07335	34.93626	36.027	24.51215	22.36868	36.23157	30.75115	33.87704	35.07335	24.05534	31.53796	25.52133	35.6017	32.2289	28.29345
52	48.07673	44.17704	35.8643	24.98917	26.14448	37.74167	34.04648	33.87964	34.91361	23.68006	21.76775	35.2498	30.17066	32.77929	34.04648	23.23542	30.73341	24.63537	34.80666	31.42436	27.50101
53	46.82025	42.96836	34.66503	24.01627	25.25323	36.61108	33.03221	32.82974	33.81068	22.88562	21.20726	34.28342	29.59079	31.699	33.03221	22.44893	29.94437	23.7823	34.01597	30.62432	26.7022
54	45.56034	41.75373	33.50479	23.05525	24.38523	35.48951	32.03225	31.78801	32.71647	22.13766	20.68603	33.33339	29.01374	30.63851	32.03225	21.69907	29.17198	22.96462	33.2283	29.82744	25.89649
55	44.29681	40.53218	32.3835	22.10497	23.54179	34.37912	31.04779	30.75699	31.63104	21.44397	20.20185	32.40034	28.44233	29.6004	31.04779	20.98887	28.4176	22.18473	32.44244	29.03227	25.08482
56	43.02916	39.30331	31.30069	21.16536	22.72421	33.28255	30.07968	29.7404	30.55646	20.81119	19.75172	31.48465	27.87984	28.58766	30.07968	20.32098	27.68267	21.4446	31.65748	28.2375	24.26973
57	41.7567	38.06749	30.25538	20.23727	21.93358	32.20298	29.12886	28.74272	29.49663	20.24427	19.33218	30.58642	27.32953	27.60351	29.12886	19.69734	26.96838	20.7458	30.87316	27.44238	23.45535
58	40.47886	36.82622	29.24602	19.32202	21.17076	31.14392	28.19674	27.76837	28.45705	19.74557	18.93951	29.70565	26.79431	26.6513	28.19674	19.1188	26.27526	20.08935	30.08979	26.64686	22.64725
59	39.19552	35.58257	28.27008	18.42085	20.43647	30.10915	27.28511	26.82078	27.44413	19.31373	18.56963	28.84236	26.27615	25.73422	27.28511	18.58513	25.60324	19.47584	29.30842	25.85147	21.85224
60	37.90722	34.34125	27.32391	17.53457	19.73128	29.1026	26.3962	25.90199	26.46444	18.94357	18.21791	27.9968	25.77613	24.8553	26.3962	18.09494	24.95159	18.90543	28.53044	25.05735	21.07804
61	36.61518	33.10816	26.40297	16.66351	19.05554	28.12826	25.53265	25.01288	25.52348	18.62703	17.87888	27.16957	25.29456	24.01724	25.53265	17.64564	24.31932	18.37789	27.75759	24.26672	20.33262
62	35.32129	31.88972	25.50239	15.80758	18.40921	27.19004	24.69719	24.154	24.6249	18.35464	17.54622	26.36155	24.83125	23.22238	24.69719	17.23355	23.70515	17.8926	26.99155	23.48355	19.62343
63	34.02796	30.6923	24.61766	14.96663	17.79187	26.29145	23.89221	23.32628	23.77017	18.11653	17.2135	25.57375	24.38604	22.47263	23.89221	16.85406	23.10743	17.44856	26.2339	22.71367	18.95674
64	32.73806	29.52149	23.74471	14.14074	17.2029	25.4353	23.11917	22.53108	22.95908	17.90301	16.8752	24.80705	23.95904	21.76925	23.11917	16.50205	22.52386	17.04418	25.48593	21.96427	18.33731
65	31.45459	28.38192	22.87968	13.33052	16.64186	24.62355	22.37843	21.76976	22.19026	17.70481	16.52787	24.06234	23.55097	21.11288	22.37843	16.17238	21.95123	16.67724	24.74868	21.24283	17.76851
66	30.18044	27.27721	22.01898	12.53732	16.10906	23.85722	21.66951	21.04331	21.46154	17.51324	16.17083	23.34056	23.16311	20.50352	21.66951	15.86038	21.38531	16.34498	24.02292	20.55551	17.25261
67	28.9182	26.20993	21.15946	11.76305	15.60569	23.13648	20.99186	20.35209	20.76952	17.32054	15.80595	22.64281	22.7971	19.94035	20.99186	15.56226	20.82137	16.04424	23.30936	19.906	16.79095
68	27.67016	25.18164	20.29869	11.01017	15.13359	22.46078	20.34523	19.6954	20.10921	17.12025	15.43692	21.97039	22.45474	19.42196	20.34523	15.27504	20.25442	15.77171	22.60872	19.29522	16.38404
69	26.43841	24.19294	19.43493	10.28169	14.69451	21.82878	19.72965	19.07111	19.47378	16.90744	15.06834	21.32466	22.1375	18.94635	19.72965	14.99658	19.67994	15.52409	21.92194	18.72188	16.03144
70	25.22482	23.24336	18.56706	9.58126	14.28927	21.23824	19.14497	18.47544	18.85498	16.67827	14.70501	20.70696	21.84617	18.51109	19.14497	14.72549	19.09419	15.29822	21.25011	18.1836	15.73165
71	24.03102	22.33127	17.69462	8.91315	13.91693	20.68606	18.5906	17.90348	18.24428	16.42956	14.3512	20.11842	21.58059	18.11349	18.5906	14.46091	18.4945	15.09112	20.59447	17.67798	15.48191
72	22.85826	21.45406	16.81779	8.28215	13.57468	20.16854	18.06532	17.35019	17.63429	16.15889	14.01044	19.55972	21.3395	17.75074	18.06532	14.20256	17.87942	14.90009	19.95631	17.20334	15.27792
73	21.70762	20.60829	15.9374	7.69329	13.25793	19.68172	17.56755	16.81174	17.02041	15.8654	13.68564	19.03103	21.12077	17.41988	17.56755	13.95057	17.24836	14.72286	19.33684	16.75884	15.11372
74	20.57992	19.78993	15.05501	7.15141	12.96095	19.22184	17.09554	16.28612	16.40175	15.55114	13.37944	18.53198	20.92161	17.11788	17.09554	13.70543	16.60164	14.55748	18.73714	16.34445	14.98195
75	19.47604	18.99479	14.17299	6.66088	12.67756	18.78555	16.64776	15.77324	15.78134	15.22223	13.09455	18.0618	20.73875	16.84164	16.64776	13.46776	15.94027	14.40232	18.15814	15.96075	14.87464
76	18.39693	18.21908	13.29476	6.22551	12.40158	18.37012	16.22292	15.27442	15.16536	14.88893	12.83374	17.61935	20.56862	16.58806	16.22292	13.23814	15.26604	14.25589	17.60049	15.60856	14.78425
77	17.34367	17.45994	12.42483	5.84827	12.12724	17.97342	15.82022	14.79171	14.56209	14.5638	12.59947	17.20304	20.40746	16.35418	15.82022	13.01695	14.58192	14.11685	17.06443	15.28848	14.70478
78	16.3174	16.71604	11.56846	5.5309	11.8496	17.59386	15.43961	14.32712	13.98056	14.25875	12.39341	16.81084	20.25144	16.13749	15.43961	12.80423	13.89241	13.98397	16.54977	15.00045	14.63189
79	15.31912	15.98767	10.7311	5.27371	11.5651	17.23036	15.08205	13.88225	13.42943	13.98266	12.21594	16.44036	20.09684	15.93608	15.08205	12.59953	13.20357	13.85618	16.05588	14.7434	14.56264
80	14.3495	15.27651	9.91768	5.0756	11.2722	16.88216	14.74954	13.4585	12.91622	13.7402	12.0661	16.0888	19.94017	15.74874	14.74954	12.40224	12.52298	13.73264	15.58185	14.51537	14.49468
81	13.40885	14.58533	9.13235	4.93408	10.972	16.54858	14.44472	13.05731	12.44681	13.53239	11.94211	15.75306	19.77822	15.57478	14.44472	12.21174	11.85899	13.61269	15.12664	14.31381	14.42564
82	12.49727	13.91746	8.37842	4.84467	10.66859	16.22894	14.17038	12.68037	12.02506	13.35787	11.84207	15.42991	19.60806	15.41372	14.17038	12.02777	11.22026	13.49583	14.6893	14.13607	14.35314
83	11.61485	13.27627	7.65874	4.80023	10.36845	15.92246	13.92911	12.32975	11.65249	13.21432	11.76439	15.11626	19.42708	15.26506	13.92911	11.85053	10.6151	13.38173	14.26906	13.97963	14.2752
84	10.76223	12.6649	6.97608	4.79076	10.07928	15.62817	13.72309	12.00788	11.32821	13.09899	11.70747	14.80958	19.23318	15.12797	13.72309	11.68074	10.0511	13.2703	13.86546	13.84213	14.19101
85	9.94077	12.08603	6.33329	4.80432	9.80876	15.34489	13.55385	11.71746	11.0492	13.0088	11.6694	14.50806	19.02503	15.00134	13.55385	11.51944	9.53492	13.16164	13.47834	13.72138	14.1012
86	9.15269	11.54168	5.73309	4.82881	9.56324	15.07131	13.42181	11.46099	10.81069	12.94025	11.64785	14.21076	18.80211	14.88378	13.42181	11.36774	9.07182	13.05618	13.10783	13.61559	14.00753
87	8.40114	11.03302	5.17773	4.85364	9.34707	14.80614	13.32571	11.24024	10.60667	12.88972	11.64048	13.91746	18.56487	14.77379	13.32571	11.22662	8.6657	12.95447	12.75427	13.52353	13.91223
88	7.68981	10.56029	4.66872	4.87048	9.16275	14.54838	13.26225	11.05584	10.4304	12.85368	11.64561	13.62838	18.31458	14.6699	13.26225	11.09666	8.31892	12.85711	12.4182	13.44457	13.81723
89	7.02256	10.12258	4.20696	4.87353	9.01124	14.2975	13.22584	10.90699	10.27512	12.82897	11.66241	13.34395	18.05313	14.57078	13.22584	10.97803	8.03222	12.76461	12.1002	13.37834	13.7239

90	6.40302	9.7179	3.79269	4.85958	8.89223	14.05366	13.20892	10.7916	10.13471	12.81249	11.69063	13.0646	17.78285	14.47522	13.20892	10.87046	7.80495	12.6773	11.80088	13.32433	13.63312
91	5.83423	9.34343	3.42541	4.82851	8.80428	13.81769	13.20255	10.70667	10.0041	12.8007	11.72983	12.7909	17.50643	14.38209	13.20255	10.77329	7.63505	12.5953	11.52072	13.28163	13.54536
92	5.31844	8.99576	3.10375	4.78363	8.74464	13.59097	13.19719	10.64872	9.87942	12.78946	11.7786	12.52364	17.22694	14.29042	13.19719	10.68572	7.51911	12.51848	11.26008	13.2487	13.46084
93	4.85669	8.67126	2.82528	4.73121	8.70925	13.37512	13.18346	10.6141	9.75788	12.77449	11.83437	12.26408	16.94795	14.1993	13.18346	10.60685	7.45262	12.44649	11.01902	13.22375	13.37971
94	4.44869	8.36626	2.58645	4.67893	8.69282	13.17165	13.15298	10.59907	9.63719	12.75218	11.89371	12.01402	16.67351	14.10801	13.15298	10.53572	7.42991	12.37887	10.79742	13.20515	13.30217
95	4.09291	8.07716	2.38263	4.63409	8.68929	12.98174	13.09932	10.59965	9.51488	12.72043	11.95295	11.77558	16.40802	14.01612	13.09932	10.47136	7.4445	12.31516	10.59494	13.19176	13.22854
96	3.78671	7.8004	2.2083	4.60276	8.69244	12.80622	13.01876	10.61162	9.38792	12.67881	12.00896	11.55099	16.15593	13.9236	13.01876	10.41264	7.48937	12.25492	10.41111	13.18299	13.15929
97	3.5266	7.53245	2.0575	4.58944	8.69644	12.6457	12.91087	10.6307	9.25255	12.62824	12.05945	11.34206	15.92134	13.83087	12.91087	10.35827	7.55732	12.1978	10.24543	13.17843	13.09496
98	3.30847	7.26989	1.92453	4.59667	8.69649	12.50056	12.77845	10.65283	9.10474	12.57035	12.10308	11.14997	15.70767	13.73872	12.77845	10.3068	7.64159	12.14346	10.09735	13.17742	13.03615
99	3.12774	7.00965	1.80451	4.6245	8.68914	12.37083	12.62707	10.67455	8.94097	12.50717	12.13939	10.97516	15.51736	13.64804	12.62707	10.25673	7.7361	12.09146	9.96635	13.1788	12.98362
100	2.97963	6.74945	1.69341	4.67028	8.67241	12.25592	12.46418	10.69328	8.75913	12.4411	12.16873	10.81741	15.35188	13.55958	12.46418	10.20659	7.83585	12.04127	9.85188	13.18104	12.93835
101	2.85935	6.48814	1.58776	4.72968	8.64565	12.15461	12.29808	10.70742	8.55951	12.37508	12.19219	10.67601	15.21188	13.47379	12.29808	10.15506	7.93686	11.99225	9.75347	13.18241	12.90128

Section A-2 Hip Angular Displacement Data for Participant A

	Hip Lift 1	Hip Lift 2	Hip Lift 3	Hip Lift 4	Hip Lift 5	Hip Lift 6	Hip Lift 7	Hip Lift 8	Hip Lift 9	Hip Lift 10	Hip Lift 11	Hip Lift 12	Hip Lift 13	Hip Lift 14	Hip Lift 15	Hip Lift 16	Hip Lift 17	Hip Lift 18	Hip Lift 19	Hip Lift 20	Hip Lift 21
1	102.9545	99.24869	95.40244	96.2319	77.96052	81.51048	80.73701	73.17435	75.53459	76.01551	75.3195	75.69746	75.94968	77.44617	80.73701	74.49451	80.13064	73.13868	74.24101	72.36305	73.80035
2	102.8953	99.16718	95.26186	96.15768	77.99793	81.54359	80.70197	73.1491	75.60471	76.05928	75.15486	75.6798	75.81389	77.48753	80.70197	74.40396	80.02988	73.14378	74.24441	72.35426	73.75497
3	102.8249	99.06982	95.11357	96.07005	78.02008	81.5584	80.66225	73.11829	75.6664	76.06988	74.98033	75.65497	75.67293	77.53273	80.66225	74.29915	79.90948	73.1329	74.24304	72.33794	73.7019
4	102.7418	98.95684	94.95829	95.96867	78.01952	81.55267	80.61823	73.0797	75.71647	76.04086	74.79778	75.62247	75.52718	77.5793	80.61823	74.18206	79.7671	73.10513	74.23447	72.31326	73.64043
5	102.6443	98.82874	94.79599	95.85382	77.98898	81.5241	80.56873	73.03191	75.75134	75.96706	74.60887	75.58089	75.37609	77.62379	80.56873	74.05424	79.60031	73.05979	74.21574	72.27747	73.56853
6	102.531	98.68626	94.62579	95.72537	77.92178	81.47002	80.51096	72.97412	75.76704	75.84424	74.41448	75.52769	75.21761	77.66154	80.51096	73.91597	79.40695	72.99597	74.18342	72.22591	73.48296
7	102.4004	98.53024	94.44595	95.58111	77.81187	81.38744	80.44054	72.90527	75.75922	75.66901	74.21388	75.45908	75.04815	77.68699	80.44054	73.766	79.185	72.91246	74.13365	72.15276	73.37941
8	102.2511	98.36163	94.25389	95.41673	77.65328	81.27355	80.35182	72.8231	75.72295	75.43911	74.00423	75.37025	74.86285	77.69368	80.35182	73.60146	78.93251	72.80757	74.06229	72.05142	73.25257
9	102.0816	98.18134	94.04638	95.22587	77.4399	81.12623	80.23873	72.7238	75.65304	75.15376	73.78036	75.25578	74.6562	77.67497	80.23873	73.41795	78.64729	72.67911	73.96517	71.9147	73.09608
10	101.8901	97.98959	93.81964	95.00055	77.16566	80.94392	80.09579	72.60218	75.54443	74.81281	73.5348	75.11026	74.42297	77.62448	80.09579	73.20998	78.32699	72.52429	73.83836	71.73552	72.90281
11	101.6747	97.78526	93.56955	94.73268	76.82526	80.72564	79.91872	72.45174	75.39294	74.41641	73.25844	74.9286	74.15852	77.53667	79.91872	72.97102	77.96939	72.33986	73.67855	71.50716	72.66508
12	101.4333	97.56598	93.29221	94.41535	76.41491	80.47077	79.70463	72.26513	75.19545	73.96431	72.9419	74.70644	73.85936	77.4071	79.70463	72.69379	77.57251	72.12199	73.48322	71.22369	72.37547
13	101.1635	97.32854	92.98441	94.04359	75.93259	80.17871	79.45109	72.03526	74.94969	73.45541	72.5767	74.44027	73.52282	77.2324	79.45109	72.37038	77.13461	71.8665	73.25076	70.88042	72.02758
14	100.8632	97.06975	92.64336	93.6143	75.3779	79.84866	79.15611	71.75645	74.65376	72.88773	72.15638	74.12738	73.14712	77.01036	79.15611	71.99277	76.6541	71.56908	72.98017	70.47423	71.61683
15	100.5305	96.78673	92.26625	93.12662	74.75154	79.47951	78.81815	71.42554	74.30582	72.25828	71.6767	73.76583	72.73141	76.73972	78.81815	71.55357	76.12958	71.2257	72.67119	70.00376	71.141
16	100.1634	96.47701	91.85077	92.58237	74.05514	79.06968	78.43649	71.04245	73.90403	71.56413	71.13536	73.35466	72.27582	76.42001	78.43649	71.04694	75.55994	70.83273	72.32376	69.46922	70.59959
17	99.76035	96.13855	91.39595	91.98492	73.29116	78.6176	78.01144	70.61002	73.44706	70.80315	70.53141	72.89368	71.78123	76.05148	78.01144	70.46886	74.94443	70.38699	71.93797	68.87202	69.99327
18	99.31972	95.76922	90.90103	91.33788	72.46272	78.12182	77.54405	70.13302	72.93491	69.97472	69.86426	72.38358	71.24915	75.63475	77.54405	69.81736	74.28277	69.88585	71.51377	68.21413	69.32334
19	98.83949	95.36651	90.36829	90.64364	71.57304	77.58123	77.0358	69.61667	72.36864	69.08022	69.13351	71.82568	70.6813	75.17085	77.0358	69.09184	73.57518	69.32727	71.05108	67.49808	68.5916
20	98.31761	94.92774	89.79763	89.90372	70.62457	76.9955	76.48849	69.06564	71.74996	68.12278	68.33923	71.22156	70.07926	74.66109	76.48849	68.2928	72.82239	68.70985	70.5495	66.72695	67.80056
21	97.75208	94.45004	89.18964	89.11739	69.61877	76.36489	75.90468	68.48288	71.08061	67.10645	67.4822	70.57262	69.4441	74.10699	75.90468	67.42168	72.02547	68.03268	70.00848	65.9043	66.95361
22	97.14137	93.93125	88.55204	88.28252	68.55643	75.69004	75.28702	67.86862	70.36221	66.03529	66.56425	69.87988	68.77681	73.51021	75.28702	66.48067	71.18577	67.29546	69.42719	65.03381	66.05486
23	96.48487	93.37022	87.88487	87.39701	67.43829	74.97181	74.63805	67.2201	69.596	64.91328	65.58797	69.14377	68.07826	72.87245	74.63805	65.47247	70.30453	66.49837	68.80474	64.11902	65.10892
24	95.78286	92.76678	87.18858	86.45804	66.26585	74.2111	73.96034	66.53214	68.78317	63.74437	64.55625	68.36406	67.34931	72.19537	73.96034	64.4	69.38293	65.64196	68.14023	63.1629	64.12069
25	95.03661	92.12222	86.46329	85.46329	65.0415	73.40872	73.25668	65.79877	67.92461	62.53231	63.47162	67.53964	66.59105	71.48034	73.25668	63.26614	68.42204	64.72697	67.43301	62.16875	63.09523
26	94.24802	91.43802	85.70733	84.41233	63.7681	72.56532	72.52957	65.01486	67.02148	61.28037	62.33602	66.66864	65.80481	70.72838	72.52957	62.07366	67.423	63.75426	66.68267	61.13989	62.03799
27	93.41916	90.7153	84.91901	83.30658	62.44835	71.68124	71.7812	64.17716	66.07542	59.99128	61.15063	65.74889	64.99227	69.94009	71.7812	60.82547	66.3874	62.72451	65.8892	60.079	60.95367
28	92.55199	89.95606	84.09685	82.14899	61.08445	70.75646	71.0135	63.28488	65.08882	58.66733	59.91589	64.77847	64.15555	69.11547	71.0135	59.52464	65.31763	61.63814	65.05286	58.98756	59.84543
29	91.64896	89.16069	83.23963	80.94363	59.67818	69.79051	70.22803	62.33948	64.06477	57.3105	58.63216	63.75655	63.29695	68.25394	70.22803	58.17437	64.21723	60.49581	64.17423	57.866	58.71451
30	90.71223	88.32907	82.34647	79.69533	58.23149	68.78293	69.42582	61.34377	63.00655	55.92268	57.30019	62.68337	62.4188	67.35423	69.42582	56.77796	63.09055	59.2988	63.25428	56.71508	57.56101
31	89.74352	87.46278	81.41694	78.40918	56.7472	67.73334	68.60667	60.30099	61.91679	54.50583	55.92147	61.56006	61.52329	66.41477	68.60667	55.33865	61.94242	58.04999	62.29432	55.5364	56.38506
32	88.74534	86.56251	80.45104	77.09036	55.22954	66.64159	67.769	59.21415	60.7967	53.06234	54.49831	60.38825	60.61261	65.43382	67.769	53.85978	60.77779	56.75349	61.2961	54.3322	55.18721
33	87.71899	85.6286	79.44918	75.7436	53.68441	65.508	66.91039	58.08561	59.64604	51.59502	53.03375	59.1698	59.68897	64.40948	66.91039	52.34484	59.60126	55.41454	60.26137	53.10481	53.96822
34	86.66454	84.66151	78.41151	74.37218	52.11904	64.33381	66.02785	56.91714	58.46383	50.10692	51.53165	57.90673	58.75464	63.34003	66.02785	50.7974	58.41676	54.03875	59.19168	51.8563	52.72892
35	85.58215	83.66133	77.33784	72.97699	50.54134	63.12143	65.1179	55.70986	57.24915	48.60096	49.99704	56.60138	57.81178	62.22411	65.1179	49.22121	57.22737	52.63178	58.08809	50.58862	51.4705
36	84.47244	82.62802	76.22786	71.55672	48.9589	61.87459	64.17647	54.46417	56.00161	47.0791	48.43597	55.25652	56.86214	61.06094	64.17647	47.62044	56.03534	51.19922	56.95138	49.30397	50.19469
37	83.33673	81.56148	75.08125	70.10947	47.37841	60.59717	63.19896	53.17987	54.72118	45.54234	46.85524	53.8754	55.90668	59.85043	63.19896	45.99981	54.84201	49.74656	55.78212	48.00499	48.90358
38	82.17696	80.46178	73.89811	68.63396	45.80548	59.29234	62.18027	51.85676	53.40818	43.99116	45.26194	52.46175	54.94565	58.59306	62.18027	44.36443	53.64796	48.2792	54.58102	46.69495	47.59972
39	80.99548	79.32929	72.6787	67.12991	44.24482	57.96196	61.1148	50.49543	52.06327	42.4262	43.66286	51.01958	53.979	57.2899	61.1148	42.71983	52.45305	46.80248	53.34922	45.37791	46.28613
40	79.79488	78.16465	71.42321	65.59828	42.70071	56.60712	59.99648	49.09803	50.68734	40.84877	42.06402	49.55326	53.00673	55.94251	59.99648	41.07164	51.25648	45.32165	52.08833	44.05818	44.96623
41	78.57758	76.96861	70.13233	64.04055	41.17735	55.22891	58.81943	47.66874	49.28098	39.26093	40.47057	48.06748	52.02943	54.55299	58.81943	39.42557	50.05696	43.84185	50.80051	42.73952	43.6437
42	77.3458	75.7421	68.80846	62.45892	39.67886	53.82877	57.57882	46.21371	47.84439	37.66512	38.88705	46.5672	51.04833	53.12421	57.57882	37.78726	48.85297	42.36801	49.48871	41.42449	42.32196

43	76.10123	74.48637	67.45607	60.85621	38.20907	52.4085	56.27194	44.74009	46.37778	36.06451	37.31767	45.05746	50.06531	51.65971	56.27194	36.16228	47.64309	40.90466	48.15643	40.11446	41.00379
44	74.84491	73.20292	66.08035	59.23565	36.77118	50.9699	54.89916	43.25487	44.88256	34.46284	35.76675	43.54342	49.08255	50.16366	54.89916	34.55624	46.42641	39.45584	46.80785	38.80994	39.69127
45	73.57737	71.89342	64.68572	57.60061	35.36744	49.51469	53.46384	41.76398	43.36268	32.86462	34.2392	42.03031	48.10245	48.64065	53.46384	32.97507	45.20277	38.02493	45.44756	37.51076	38.38598
46	72.29882	70.55958	63.27556	55.95402	33.99919	48.04453	51.97226	40.27198	41.82487	31.27545	32.7404	40.5233	47.12741	47.09558	51.97226	31.42515	43.97299	36.61496	44.08041	36.21649	37.08934
47	71.00929	69.20307	61.85281	54.29805	32.66683	46.56102	50.43321	38.78196	40.2775	29.70242	31.27602	39.0272	46.1595	45.53362	50.43321	29.91323	42.73855	35.22852	42.71133	34.92689	35.80272
48	69.70892	67.82565	60.42022	52.63398	31.37006	45.06582	48.85734	37.29541	38.72928	28.15436	29.85151	37.54608	45.20024	43.96011	48.85734	28.44608	41.50149	33.86806	41.34499	33.64226	34.52757
49	68.39771	66.42944	58.97997	50.96298	30.10858	43.56061	47.25626	35.81224	37.18842	26.64204	28.472	36.08314	44.25043	42.38061	47.25626	27.02998	40.26416	32.53598	39.98555	32.36367	33.26517
50	67.07555	65.01688	57.53324	49.28698	28.88207	42.04737	45.64076	34.33097	35.66222	25.17803	27.14247	34.641	43.31007	40.80084	45.64076	25.6706	39.0288	31.23472	38.63643	31.09275	32.017
51	65.74236	63.59027	56.08046	47.60906	27.69015	40.52846	44.01989	32.84957	34.15687	23.77542	25.86787	33.22234	42.37879	39.22671	44.01989	24.3728	37.79717	29.96681	37.30029	29.83183	30.78476
52	64.39817	62.15152	54.62185	45.93277	26.5322	39.00666	42.40085	31.36646	32.67698	22.44613	24.65252	31.83034	41.45596	37.6643	42.40085	23.14037	36.57043	28.7349	35.97882	28.58454	29.57038
53	63.04302	60.70218	53.15774	44.26161	25.40712	37.48539	40.78888	29.88148	31.22575	21.19939	23.4995	30.46854	40.54085	36.11981	40.78888	21.97617	35.34954	27.54179	34.6732	27.35609	28.37622
54	61.6769	59.24366	51.68935	42.59836	24.31361	35.96854	39.18752	28.39668	29.80572	20.04052	22.41017	29.14073	39.63293	34.59969	39.18752	20.88208	34.13566	26.39029	33.38411	26.15268	27.20515
55	60.2995	57.77751	50.21888	40.94534	23.25052	34.46051	37.59915	26.91673	28.41933	18.97076	21.38411	27.85032	38.73198	33.11066	37.59915	19.85888	32.93013	25.28312	32.11227	24.98008	26.06055
56	58.91016	56.30553	48.74937	39.30518	22.21722	32.96618	36.02589	25.44872	27.06878	17.98813	20.4198	26.60012	37.83797	31.65949	36.02589	18.90643	31.73451	24.22262	30.85865	23.84282	24.94617
57	57.50795	54.82975	47.28429	37.68091	21.2138	31.49083	34.47075	24.00143	25.7561	17.0882	19.51458	25.39212	36.95101	30.2527	34.47075	18.02375	30.55037	23.21078	29.62459	22.74431	23.86605
58	56.09204	53.35249	45.82703	36.07574	20.24122	30.03997	32.93835	22.58425	24.48356	16.26496	18.66486	24.2275	36.07124	28.89613	32.93835	17.20868	29.37914	22.24903	28.41175	21.68705	22.8243
59	54.66233	51.87665	44.38021	34.49283	19.30122	28.61926	31.43421	21.20598	23.25364	15.5118	17.86611	23.10694	35.19869	27.59451	31.43421	16.45787	28.22232	21.33789	27.22216	20.67266	21.82483
60	53.21971	50.40562	42.94531	32.93517	18.3958	27.2347	29.96407	19.87396	22.06881	14.82199	17.11268	22.0308	34.33367	26.35152	29.96407	15.76663	27.08168	20.47714	26.05781	19.70194	20.87102
61	51.76653	48.94302	41.5229	31.40529	17.52658	25.8923	28.5333	18.59419	20.93206	14.18859	16.39826	20.99922	33.47696	25.16961	28.5333	15.12894	25.9602	19.66582	24.92043	18.77477	19.96483
62	50.30639	47.49237	40.1134	29.90517	16.69407	24.5978	27.14645	17.37186	19.84737	13.60447	15.71669	20.01195	32.63002	24.05009	27.14645	14.53798	24.86215	18.90241	23.8114	17.89086	19.10705
63	48.8438	46.057	38.71793	28.43722	15.89788	23.35612	25.80621	16.21191	18.81985	13.06254	15.06277	19.06829	31.7947	22.99319	25.80621	13.98661	23.79321	18.18488	22.73182	17.05015	18.29756
64	47.3837	44.63958	37.33882	27.00477	15.13684	22.17097	24.51229	15.11907	17.85426	12.55609	14.43293	18.16723	30.97318	21.998	24.51229	13.46803	22.75888	17.5106	21.68239	16.25291	17.53594
65	45.93095	43.24249	35.97905	25.61247	14.40947	21.04488	23.26112	14.09715	16.95292	12.07951	13.82544	17.30799	30.16812	21.06275	23.26112	12.97609	21.76352	16.8764	20.66379	15.49968	16.82183
66	44.49001	41.86799	34.6417	24.26552	13.71491	19.97921	22.04682	13.14834	16.11526	11.62869	13.24014	16.49001	29.38205	20.18494	22.04682	12.50564	20.80843	16.27861	19.6769	14.79045	16.15491
67	43.06469	40.51825	33.32955	22.9686	13.05366	18.9742	20.86344	12.2727	15.33833	11.20147	12.67776	15.71295	28.6174	19.36119	20.86344	12.05267	19.8923	15.71323	18.72295	14.12387	15.5346
68	41.65811	39.19507	32.04483	21.72412	12.42761	18.02911	19.70736	11.46809	14.61765	10.79789	12.13916	14.97679	27.87635	18.58777	19.70736	11.61427	19.01154	15.17618	17.80355	13.49731	14.95968
69	40.27269	37.89967	30.78936	20.53198	11.83974	17.14232	18.57964	10.73057	13.94754	10.41954	11.625	14.28175	27.16039	17.86086	18.57964	11.18869	18.16164	14.66358	16.9206	12.90785	14.42823
70	38.91023	36.63262	29.56488	19.38991	11.29331	16.31137	17.48736	10.05474	13.32197	10.0682	11.13556	13.62824	26.4705	17.17695	17.48736	10.7752	17.33827	14.17174	16.07588	12.3533	13.9377
71	37.572	35.39407	28.37299	18.29459	10.79056	15.53308	16.44181	9.43444	12.73555	9.74455	10.67065	13.01681	25.80728	16.5332	16.44181	10.37382	16.53817	13.69722	15.27068	11.83249	13.48487
72	36.25904	34.18383	27.21486	17.2432	10.3322	14.80368	15.4533	8.86367	12.18447	9.44726	10.22993	12.44758	25.17087	15.92766	15.4533	9.98527	15.75956	13.23692	14.50566	11.34385	13.06563
73	34.97242	33.00136	26.09149	16.23438	9.91752	14.11887	14.52794	8.33754	11.66768	9.17324	9.81325	11.92016	24.56112	15.35902	14.52794	9.61071	15.00182	12.78822	13.78086	10.88403	12.67477
74	33.7133	31.84596	25.00331	15.26838	9.54473	13.4744	13.66671	7.85267	11.18683	8.91827	9.42101	11.43354	23.97771	14.82631	13.66671	9.25159	14.26525	12.3491	13.09579	10.4477	12.3061
75	32.4831	30.71707	23.95063	14.34715	9.2116	12.86635	12.86692	7.40693	10.74544	8.67766	9.05425	10.98619	23.4198	14.32874	12.86692	8.90958	13.55064	11.91832	12.44963	10.02856	11.95293
76	31.28346	29.61457	22.93401	13.47425	8.91568	12.29123	12.12435	6.99895	10.34713	8.44758	8.71432	10.5759	22.88622	13.86534	12.12435	8.5862	12.85913	11.49522	11.84133	9.62092	11.609
77	30.11601	28.53901	21.95408	12.65431	8.65425	11.74642	11.43424	6.62776	9.99409	8.22555	8.40225	10.1996	22.37545	13.43482	11.43424	8.28252	12.19204	11.07972	11.26963	9.22111	11.26966
78	28.98238	27.49185	21.01174	11.8921	8.42445	11.23027	10.79163	6.2921	9.68618	8.00966	8.11845	9.85356	21.88575	13.03555	10.79163	7.99879	11.55088	10.67252	10.73309	8.82775	10.93214
79	27.88402	26.47496	20.10793	11.19117	8.22332	10.74228	10.19103	5.98999	9.42118	7.79776	7.86243	9.53376	21.41574	12.66559	10.19103	7.73394	10.93764	10.27485	10.23011	8.44149	10.59528
80	26.82207	25.4904	19.24386	10.55345	8.04786	10.28286	9.62572	5.719	9.19524	7.58679	7.63262	9.23625	20.96451	12.32273	9.62572	7.48593	10.35513	9.88843	9.759	8.06436	10.25892
81	25.79766	24.54012	18.42114	9.97933	7.8951	9.85263	9.08745	5.47644	9.00255	7.37282	7.42673	8.95742	20.53185	12.00481	9.08745	7.25192	9.80612	9.51531	9.3179	7.69918	9.92322
82	24.81176	23.62617	17.64181	9.46751	7.76184	9.45201	8.5672	5.25941	8.83576	7.15229	7.24254	8.69395	20.11761	11.70949	8.5672	7.02852	9.29302	9.15759	8.90477	7.34901	9.5885
83	23.86501	22.75039	16.90815	9.01436	7.64471	9.08083	8.05703	5.06428	8.68665	6.92344	7.07795	8.44302	19.72133	11.43406	8.05703	6.81222	8.81775	8.81726	8.51734	7.01671	9.25548
84	22.95785	21.91435	16.22216	8.61309	7.54026	8.73837	7.55284	4.88681	8.54743	6.68765	6.93096	8.20242	19.34181	11.17535	7.55284	6.59971	8.38097	8.49608	8.15343	6.70465	8.92569
85	22.09061	21.11906	15.58522	8.25402	7.44516	8.42353	7.05649	4.72202	8.41162	6.44918	6.79932	7.97094	18.97727	10.92992	7.05649	6.38798	7.9819	8.19561	7.81089	6.41513	8.60183
86	21.26349	20.36473	14.99759	7.92633	7.35647	8.13506	6.57584	4.56454	8.27438	6.21425	6.68018	7.74849	18.62578	10.69435	6.57584	6.17438	7.61879	7.91715	7.48762	6.15089	8.28755
87	20.47684	19.65054	14.45784	7.62016	7.27139	7.87148	6.12319	4.4093	8.13241	5.98964	6.57048	7.5358	18.28581	10.46557	6.12319	5.95672	7.28978	7.66171	7.18165	5.91509	7.98684
88	19.73128	18.97461	13.963	7.32757	7.18758	7.63107	5.7129	4.25204	7.9838	5.78146	6.46731	7.33382	17.95659	10.24102	5.7129	5.73374	6.99335	7.43001	6.89128	5.71117	7.70306
89	19.02759	18.33394	13.50903	7.04314	7.1034	7.41183	5.35854	4.08953	7.82829	5.59479	6.36848	7.14334	17.63809	10.01906	5.35854	5.50495	6.72836	7.22255	6.61515	5.54237	7.43799
90	18.36661	17.72473	13.09153	6.76413	7.01808	7.21163	5.0696	3.91983	7.66688	5.43362	6.2729	6.96461	17.33086	9.79865	5.0696	5.27084	6.49386	7.03948	6.35233	5.41085	7.19139

91	17.7489	17.14277	12.70634	6.49072	6.93187	7.02862	4.8495	3.74257	7.50135	5.30029	6.18044	6.79713	17.036	9.57929	4.8495	5.03316	6.2888	6.88052	6.10237	5.31646	6.96098
92	17.1745	16.58394	12.34993	6.2256	6.84573	6.8615	4.69401	3.5591	7.33433	5.19493	6.09129	6.63983	16.75492	9.36083	4.69401	4.79464	6.1106	6.7446	5.86516	5.25504	6.74374
93	16.64262	16.04482	12.01925	5.97263	6.76084	6.70964	4.59025	3.37264	7.16923	5.11502	6.00567	6.49151	16.48923	9.14314	4.59025	4.55891	5.9556	6.62994	5.64093	5.21838	6.53724
94	16.15162	15.52285	11.71142	5.73543	6.67804	6.57282	4.51717	3.18789	7.00974	5.05568	5.92338	6.35083	16.24073	8.926	4.51717	4.33057	5.81943	6.53396	5.43003	5.19633	6.34034
95	15.69904	15.0164	11.42347	5.51686	6.59772	6.45096	4.45089	3.01029	6.85928	5.01063	5.84373	6.21656	16.01128	8.70923	4.45089	4.11492	5.69813	6.4535	5.23284	5.17938	6.1532
96	15.28181	14.52466	11.15229	5.31903	6.51953	6.34398	4.37074	2.84494	6.72036	4.97342	5.76593	6.08786	15.80259	8.49303	4.37074	3.91773	5.58831	6.38529	5.04975	5.16056	5.97655
97	14.89657	14.04726	10.89481	5.14348	6.44261	6.25152	4.26362	2.69556	6.59435	4.93833	5.68947	5.96384	15.61592	8.27849	4.26362	3.74478	5.48726	6.32629	4.8811	5.13585	5.8112
98	14.53998	13.58405	10.64882	4.99093	6.366	6.17301	4.12492	2.56435	6.48199	4.90054	5.61441	5.84364	15.4517	8.0678	4.12492	3.60118	5.39333	6.2742	4.72718	5.1035	5.6577
99	14.20897	13.13489	10.41283	4.86062	6.28854	6.10774	3.95634	2.45201	6.38367	4.85635	5.54119	5.72658	15.3092	7.86407	3.95634	3.49096	5.30626	6.22748	4.58822	5.06295	5.51676
100	13.90075	12.69991	10.18593	4.75017	6.20917	6.05486	3.76359	2.35823	6.29891	4.80376	5.4703	5.61224	15.18626	7.67128	3.76359	3.41658	5.22793	6.1856	4.46436	5.0144	5.3896
101	13.61299	12.27945	9.96735	4.65702	6.1271	6.01334	3.55526	2.28227	6.2259	4.74295	5.40196	5.50053	15.07969	7.49374	3.55526	3.37867	5.16153	6.14854	4.35571	4.95848	5.27796

Section A-3 Knee Angular Velocity Data for Participant A

	Knee Lift 1	Knee Lift 2	Knee Lift 3	Knee Lift 4	Knee Lift 5	Knee Lift 6	Knee Lift 7	Knee Lift 8	Knee Lift 9	Knee Lift 10	Knee Lift 11	Knee Lift 12	Knee Lift 13	Knee Lift 14	Knee Lift 15	Knee Lift 16	Knee Lift 17	Knee Lift 18	Knee Lift 19	Knee Lift 20	Knee Lift 21
1	12.16008	7.26078	8.83589	29.56247	31.97835	30.28345	31.40739	23.17994	22.54912	31.07716	11.79072	16.33573	16.81222	36.46518	31.40739	13.57866	17.9406	17.4489	25.25546	11.51887	18.48307
2	14.29486	9.18333	10.30474	31.90968	35.17563	32.74771	34.7567	24.24397	24.42295	34.28318	14.95178	18.21604	19.92949	39.23469	34.7567	21.97202	22.34844	21.28884	27.85863	16.62823	24.12472
3	16.53784	11.37909	11.86744	34.00175	38.30532	35.12414	37.8139	25.18026	26.10153	37.26232	18.32401	20.02141	23.12009	41.87774	37.8139	30.72548	26.72601	25.17717	30.49328	22.04956	29.97856
4	18.87558	13.84212	13.53946	35.86024	41.28906	37.39779	40.57072	26.01598	27.55069	39.93619	21.84612	21.7681	26.35759	44.41195	40.57072	39.572	31.00248	29.04498	33.15268	27.65618	35.93882
5	21.28934	16.55486	15.35897	37.50608	44.07641	39.58263	43.04599	26.78547	28.76933	42.29117	25.46708	23.48672	29.61862	46.86089	43.04599	48.23737	35.1087	32.82069	35.8472	33.30408	41.90498
6	23.75423	19.48733	17.37292	38.97318	46.674	41.71605	45.27337	27.54511	29.79989	44.36958	29.14167	25.21543	32.87586	49.24635	45.27337	56.47166	38.98758	36.44239	38.59477	38.84872	47.78127
7	26.24688	22.59889	19.61773	40.33699	49.15716	43.83798	47.29057	28.37454	30.72058	46.2304	32.83049	27.00309	36.09597	51.58384	47.29057	64.06316	42.60056	39.86397	41.41439	44.17064	53.47876
8	28.75159	25.8452	22.11071	41.72958	51.63921	45.9819	49.12817	29.36373	31.62554	47.91656	36.51024	28.91062	39.2386	53.87833	49.12817	70.84432	45.93207	43.06224	44.30808	49.20734	58.92461
9	31.26705	29.18543	24.8605	43.31113	54.23379	48.16967	50.80461	30.60222	32.60486	49.4622	40.1863	31.01136	42.25518	56.12054	50.80461	76.69952	48.98659	46.04181	47.25828	53.95776	64.06721
10	33.80507	32.59087	27.8744	45.21294	57.0252	50.4149	52.32652	32.17876	33.73355	50.92309	43.8817	33.37747	45.09494	58.29131	52.32652	81.5659	51.78281	48.83108	50.21706	58.44619	68.87722
11	36.38389	36.04106	31.15761	47.50035	60.05395	52.73274	53.692	34.17964	35.08312	52.38327	47.61364	36.06281	47.7106	60.36483	53.692	85.43799	54.35222	51.48379	53.11985	62.68077	73.33734
12	39.02232	39.51547	34.7115	50.17638	63.32804	55.14688	54.89502	36.675	36.72703	53.92933	51.37351	39.08664	50.06622	62.31823	54.89502	88.38235	56.73809	54.06935	55.89235	66.63438	77.41821
13	41.73627	42.9855	38.54476	53.19918	66.8331	57.69445	55.93221	39.68602	38.71138	55.62798	55.12394	42.42795	52.14286	64.13523	55.93221	90.5167	58.99103	56.6636	58.47606	70.26215	81.06683
14	44.53807	46.41443	42.66964	56.49146	70.53506	60.41959	56.8023	43.16453	41.0255	57.51879	58.81211	46.04106	53.93746	65.81286	56.8023	91.99127	61.16502	59.33361	60.83232	73.53094	84.21255
15	47.43545	49.76453	47.07639	59.95267	74.37551	63.36361	57.50108	46.99178	43.60103	59.60813	62.3866	49.86703	55.46191	67.36119	57.50108	92.96038	63.30523	62.12568	62.95847	76.42045	86.81279
16	50.42951	53.0045	51.71197	63.48943	78.26837	66.54781	58.01796	51.00101	46.33137	61.85369	65.81475	53.84586	56.73846	68.80316	58.01796	93.57607	65.44382	65.06071	64.87424	78.91459	88.88174
17	53.5169	56.11948	56.47729	67.0339	82.10848	69.94795	58.34822	55.01493	49.09484	64.16309	69.09359	57.91423	57.80165	70.17374	58.34822	93.99021	67.59346	68.12811	66.61956	81.00246	90.4916
18	56.69079	59.11992	61.24395	70.54411	85.78945	73.48926	58.49342	58.87527	51.79313	66.41061	72.24725	62.00341	58.70227	71.50969	58.49342	94.36155	69.75328	71.29612	68.24287	82.69452	91.74463
19	59.94029	62.04042	65.87057	73.99724	89.22545	77.04736	58.45819	62.45319	54.37411	68.46913	75.30631	66.03748	59.50775	72.84453	58.45819	94.84547	71.91138	74.51595	69.79512	84.03696	92.73098
20	63.24328	64.93158	70.22514	77.37324	92.35613	80.47541	58.25182	65.66501	56.82906	70.23329	78.27537	69.94267	60.28856	74.20499	58.25182	95.58378	74.04546	77.73389	71.32253	85.10279	93.51215
21	66.56268	67.83317	74.21331	80.62601	95.13182	83.63042	57.901	68.48049	59.17032	71.62365	81.10912	73.65206	61.10527	75.60955	57.901	96.68565	76.1291	80.89768	72.86158	85.96544	94.11588
22	69.84301	70.75117	77.80267	83.65609	97.50096	86.3907	57.45404	70.91336	61.40602	72.58286	83.7164	77.10951	61.98919	77.06466	57.45404	98.2162	78.13551	83.96194	74.43462	86.67538	94.53886
23	73.02065	73.6552	81.02066	86.31766	99.40623	88.67158	56.97163	72.99031	63.52922	73.0778	85.99236	80.27027	62.9399	78.55988	56.97163	100.191	80.04428	86.89185	76.04749	87.2507	94.75524
24	76.03605	76.4912	83.91919	88.47157	100.8006	90.43731	56.5145	74.72405	65.52419	73.10373	87.8569	83.10453	63.92468	80.07231	56.5145	102.5635	81.84057	89.66537	77.69211	87.67967	94.72437
25	78.84699	79.20918	86.5361	90.05006	101.6669	91.70544	56.1329	76.10883	67.36873	72.68529	89.26849	85.60211	64.88508	81.57134	56.1329	105.2326	83.51405	92.28046	79.34364	87.93507	94.40533
26	81.43922	81.77366	88.87575	91.08464	102.0263	92.54833	55.86273	77.12383	69.03678	71.87608	90.21951	87.76902	65.74958	83.03188	55.86273	108.0542	85.05637	94.75558	80.96669	88.00651	93.78707
27	83.82126	84.16673	90.91675	91.67897	101.9343	93.06895	55.72681	77.74129	70.50516	70.75806	90.72619	89.61639	66.44154	84.4397	55.72681	110.8554	86.46182	97.12027	82.51459	87.91686	92.90974
28	86.01861	86.38426	92.64193	91.95644	101.462	93.37636	55.74023	77.94737	71.75786	69.43449	90.81978	91.15406	66.88994	85.80101	55.74023	113.4626	87.72702	99.38934	83.93385	87.70688	91.84612
29	88.06046	88.43267	94.05617	92.0135	100.6763	93.56403	55.91711	77.76787	72.79715	68.01187	90.54194	92.39195	67.03524	87.13489	55.91711	115.7167	88.84396	101.5406	85.16689	87.39377	90.66705
30	89.97386	90.32391	95.1824	91.91019	99.63543	93.69898	56.27592	77.27477	73.66474	66.58494	89.9464	93.3499	66.83414	88.47065	56.27592	117.4925	89.79504	103.5107	86.15929	86.94835	89.4025
31	91.78242	92.06895	96.05298	91.6956	98.39531	93.83153	56.83666	76.57753	74.4461	65.22673	89.09905	94.06238	66.2679	89.84304	56.83666	118.7072	90.54955	105.2248	86.87082	86.31024	88.05774
32	93.50902	93.66973	96.70864	91.4163	97.02193	94.001	57.6123	75.80496	75.23038	63.97902	88.06836	94.57847	65.34473	91.28709	57.6123	119.3195	91.07363	106.6264	87.29302	85.42124	86.63413
33	95.17068	95.12115	97.21214	91.09872	95.59765	94.23674	58.6055	75.08561	76.05515	62.856	86.90769	94.95133	64.09972	92.83295	58.6055	119.3295	91.34039	107.6979	87.45391	84.25738	85.1446
34	96.77259	96.41412	97.65182	90.73453	94.21501	94.55859	59.81095	74.53461	76.89005	61.86232	85.63888	95.23069	62.59584	94.49083	59.81095	118.7628	91.34161	108.4468	87.41581	82.84344	83.60546
35	98.29936	97.53922	98.12582	90.28232	92.96202	94.97453	61.21382	74.24596	77.66393	61.0142	84.25668	95.45384	60.91795	96.24779	61.21382	117.6606	91.09518	108.8904	87.25191	81.24025	82.02981
36	99.72134	98.48862	98.71868	89.68321	91.8979	95.47498	62.7882	74.28622	78.31285	60.35077	82.74623	95.64201	59.16517	98.05988	62.7882	116.0733	90.63996	109.0422	87.03172	79.5238	80.42677
37	101.0037	99.25655	99.48373	88.88791	91.03065	96.02824	64.50183	74.68596	78.8211	59.92595	81.09595	95.80291	57.44148	99.86696	64.50183	114.0586	90.03109	108.9149	86.80075	77.76604	78.80449
38	102.1167	99.84027	100.4463	87.87719	90.31625	96.58904	66.32204	75.42497	79.23238	59.78361	79.30321	95.93356	55.8362	101.6027	66.32204	111.6791	89.32639	108.5226	86.58711	76.02231	77.17422
39	103.047	100.2447	101.6138	86.6511	89.67268	97.11002	68.21719	76.42972	79.62245	59.93193	77.37571	96.02088	54.41535	103.2088	68.21719	109.0027	88.5793	107.8852	86.40121	74.32833	75.55322
40	103.7999	100.4843	102.9383	85.20659	89.0065	97.55891	70.1505	77.58471	80.0569	60.33771	75.33444	96.04317	53.21342	104.6395	70.1505	106.1061	87.82841	107.0228	86.24265	72.70634	73.96505
41	104.4022	100.5813	104.2713	83.53324	88.23898	97.92464	72.07431	78.75576	80.56248	60.94236	73.20652	95.97189	52.24269	105.8623	72.07431	103.0776	87.09206	105.9551	86.1033	71.17055	72.43744

42	104.8996	100.5605	105.3692	81.62865	87.31998	98.2181	73.93068	79.81936	81.12022	61.68073	71.00745	95.77917	51.50289	106.8589	73.93068	100.0187	86.36806	104.7021	85.96678	69.7348	70.99827
43	105.3431	100.4477	106.0155	79.52937	86.23323	98.46379	75.65768	80.68584	81.67123	62.4821	68.73211	95.44341	50.98679	107.6197	75.65768	97.02621	85.63418	103.2815	85.81326	68.41276	69.67386
44	105.7771	100.2716	106.1251	77.3225	84.99406	98.68424	77.19747	81.30765	82.13025	63.26188	66.36353	94.95304	50.67783	108.1425	77.19747	94.17397	84.86126	101.7064	85.62108	67.20858	68.4893
45	106.2222	100.0655	105.7135	75.11869	83.63579	98.89157	78.50482	81.67999	82.41104	63.92047	63.89266	94.30956	50.54977	108.4278	78.50482	91.48824	84.01981	99.97913	85.3744	66.10777	67.47015
46	106.6784	99.86459	104.8222	73.00852	82.19761	99.08081	79.55165	81.83441	82.45427	64.35798	61.3211	93.5248	50.56757	108.4772	79.55165	88.94384	83.09041	98.09552	85.06375	65.08908	66.64075
47	107.1301	99.69617	103.4709	71.0418	80.71402	99.23888	80.32584	81.82663	82.2421	64.48835	58.65344	92.61757	50.69632	108.2924	80.32584	86.48008	82.0629	96.04715	84.68998	64.14289	66.02096
48	107.5584	99.57745	101.6825	69.23853	79.20532	99.35027	80.82413	81.72152	81.79212	64.23838	55.89293	91.60745	50.90352	107.8745	80.82413	84.0167	80.9361	93.82646	84.26217	63.27819	65.62394
49	107.9504	99.52012	99.50512	67.61181	77.67197	99.39926	81.04533	81.57259	81.15342	63.53699	53.04326	90.50968	51.15781	107.223	81.04533	81.47803	79.71404	91.42566	83.80014	62.51596	65.45611
50	108.3004	99.54747	97.01162	66.18267	76.09784	99.36111	80.993	81.40362	80.40926	62.31255	50.11329	89.33195	51.41995	106.3347	80.993	78.80054	78.40113	88.83379	83.33259	61.87575	65.51381
51	108.6088	99.69173	94.28808	64.9716	74.45564	99.2019	80.68114	81.20267	79.66199	60.50464	47.12584	88.07162	51.63875	105.2061	80.68114	75.93922	76.9985	86.03545	82.89471	61.36502	65.77754
52	108.8833	99.98251	91.42179	63.9736	72.71384	98.88203	80.13791	80.93094	78.98155	58.07991	44.12527	86.72154	51.75154	103.8332	80.13791	72.86546	75.50025	83.01392	82.51958	60.97445	66.20407
53	109.1401	100.4216	88.49053	63.14934	70.84569	98.36685	79.40053	80.53902	78.35418	55.04298	41.17551	85.27886	51.69138	102.2069	79.40053	69.56578	73.89661	79.76077	82.23113	60.686	66.71584
54	109.4049	100.9806	85.55733	62.44207	68.83858	97.62621	78.50259	79.97168	77.68728	51.43555	38.34729	83.75282	51.39826	100.309	78.50259	66.04366	72.17752	76.281	82.03157	60.48236	67.20332
55	109.7057	101.6073	82.67096	61.79721	66.70022	96.63175	77.4624	79.1702	76.86197	47.32714	35.69964	82.16219	50.82712	98.11182	77.4624	62.32491	70.34357	72.59499	81.90049	60.34473	67.5362
56	110.0628	102.2315	79.8709	61.16547	64.45844	95.35304	76.27661	78.08174	75.77254	42.81464	33.27125	80.52755	49.96012	95.58772	76.27661	58.45668	68.41017	68.7364	81.79449	60.24342	67.57728
57	110.4787	102.7611	77.19605	60.50627	62.14985	93.7618	74.92205	76.67622	74.3385	38.0492	31.08782	78.86572	48.81355	92.71928	74.92205	54.50813	66.41434	64.74498	81.65735	60.14309	67.19521
58	110.9277	103.0835	74.6964	59.79669	59.80492	91.83493	73.36877	74.96169	72.50745	33.25515	29.17572	77.1863	47.43606	89.50676	73.36877	50.56056	64.40307	60.66274	81.43025	60.00893	66.27706
59	111.3652	103.0771	72.43259	59.03302	57.44328	89.55778	71.58924	72.98161	70.26529	28.69763	27.57438	75.48946	45.90356	85.96703	71.58924	46.70092	62.42477	56.53135	81.06557	59.80107	64.74246
60	111.7348	102.6381	70.45998	58.22379	55.0774	86.92715	69.56445	70.79155	67.64939	24.61407	26.341	73.76565	44.2943	82.12849	69.56445	43.01725	60.51641	52.39224	80.53222	59.4552	62.56008
61	111.9801	101.7033	68.80854	57.38025	52.72335	83.95244	67.29105	68.43181	64.7521	21.15857	25.53976	71.99838	42.67234	78.02876	67.29105	39.59647	58.70968	48.28762	79.82065	58.86541	59.76082
62	112.0497	100.2569	67.47269	56.50535	50.40361	80.65799	64.79424	65.91389	61.70168	18.39622	25.20879	70.17557	41.06826	73.71563	64.79424	36.51649	57.03844	44.26427	78.93997	57.90466	56.42689
63	111.9024	98.33055	66.42895	55.58665	48.13472	77.0875	62.13671	63.24003	58.62691	16.33091	25.32222	68.29228	39.47401	69.24613	62.13671	33.8362	55.55674	40.37475	77.91172	56.46833	52.6698
64	111.5133	95.98833	65.66274	54.59611	45.91142	73.30042	59.40686	60.42999	55.62605	14.93612	25.77233	66.34969	37.85285	64.68672	59.40686	31.57793	54.33578	36.67955	76.76453	54.51901	48.60022
65	110.878	93.30823	65.16527	53.49646	43.69452	69.3669	56.69053	57.52503	52.76568	14.1701	26.38472	64.34577	36.15123	60.10828	56.69053	29.72864	53.45696	33.23452	75.52402	52.11417	44.30823
66	110.0083	90.372	64.91853	52.25582	41.4207	65.36056	54.03673	54.58496	50.11226	13.97596	26.965	62.2733	34.32307	55.58345	54.03673	28.24031	52.98593	30.08475	74.20639	49.40051	39.86732
67	108.9258	87.26085	64.88578	50.85352	39.03394	61.35441	51.4515	51.68941	47.75898	14.27775	27.35058	60.12027	32.34315	51.18081	51.4515	27.04716	52.95813	27.25308	72.81262	46.56621	35.34511
68	107.6506	84.05788	65.01929	49.26717	36.51498	57.42343	48.9245	48.94435	45.82405	14.9848	27.43918	57.87596	30.21923	46.96064	48.9245	26.07948	53.36839	24.74581	71.33154	43.78132	30.81818
69	106.203	80.84967	65.2709	47.46567	33.90337	53.64721	46.45366	46.47276	44.41575	16.00845	27.19458	55.53524	27.99759	42.9711	46.45366	25.27244	54.16729	22.55395	69.74615	41.15144	26.37933
70	104.6048	77.72598	65.59274	45.41209	31.29707	50.1058	44.05718	44.37898	43.58642	17.27472	26.63409	53.10276	25.75206	39.24395	44.05718	24.57024	55.27624	20.65781	68.04209	38.69991	22.13757
71	102.8826	74.77366	65.9342	43.06947	28.8261	46.8642	41.76447	42.70454	43.29658	18.71078	25.80385	50.59747	23.57393	35.79882	41.76447	23.92388	56.59546	19.02952	66.21512	36.38488	18.21666
72	101.0613	72.06771	66.24023	40.41255	26.62252	43.96095	39.59878	41.3985	43.40225	20.21377	24.75002	48.04826	21.54849	32.64506	39.59878	23.29071	58.02469	17.63351	64.27061	34.13602	14.74909
73	99.15993	69.66356	66.45319	37.44139	24.79206	41.39969	37.56734	40.33143	43.67389	21.62294	23.49919	45.49003	19.74336	29.78846	37.56734	22.63712	59.47018	16.43433	62.22301	31.88534	11.85163
74	97.18529	67.58765	66.50955	34.18078	23.39913	39.15717	35.6608	39.34272	43.8469	22.71716	22.05565	42.95708	18.20335	27.23199	35.6608	21.94168	60.84973	15.40088	60.09331	29.58779	9.59296
75	95.13392	65.8289	66.33566	30.66651	22.46913	37.19053	33.85901	38.28704	43.68061	23.2543	20.41362	40.48447	16.95359	24.97422	33.85901	21.1984	62.07906	14.51286	57.90819	27.23216	7.96709
76	92.99638	64.3345	65.85268	26.94275	21.99286	35.4457	32.13228	37.07045	43.00348	23.05402	18.57861	38.10919	16.00764	23.00177	32.13228	20.41779	63.06187	13.75705	55.70283	24.84363	6.88377
77	90.7646	63.00993	64.99355	23.07256	21.92872	33.86492	30.43408	35.66774	41.73035	22.0782	16.58588	35.87106	15.37055	21.28636	30.43408	19.62275	63.67622	13.12404	53.51638	22.476	6.21065
78	88.44118	61.73146	63.72682	19.13606	22.19743	32.39485	28.69899	34.10975	39.85719	20.44471	14.50694	33.8098	15.03943	19.77838	28.69899	18.84425	63.78829	12.6015	51.38995	20.19472	5.82167
79	86.04073	60.37391	62.06815	15.2193	22.67317	30.99519	26.85125	32.44444	37.44203	18.37162	12.43258	31.96339	15.00566	18.42073	26.85125	18.10608	63.26916	12.17337	49.35312	18.05748	5.63781
80	83.58767	58.83043	60.07156	11.41142	23.18438	29.64709	24.82742	30.70613	34.58208	16.0929	10.44169	30.36524	15.2568	17.15728	24.82742	17.41549	62.02608	11.82004	47.42332	16.09892	5.63929
81	81.10158	57.03018	57.80583	7.82512	23.52871	28.34913	22.59604	28.89996	31.39785	13.7916	8.57393	29.03679	15.7791	15.9534	22.59604	16.7583	60.0156	11.52157	45.59706	14.32534	5.82951
82	78.58543	54.94436	55.32589	4.61533	23.51072	27.11368	20.15716	27.00123	28.02979	11.57646	6.83117	27.97983	16.55228	14.79688	20.15716	16.10348	57.24384	11.25722	43.85833	12.72399	6.19704
83	76.01518	52.57847	52.65513	1.96655	22.99054	25.96197	17.53552	24.96685	24.63296	9.50358	5.20867	27.16844	17.54415	13.70068	17.53552	15.41633	53.76343	11.00484	42.17904	11.27904	6.68448
84	73.33942	49.96508	49.7923	0.03863	21.91167	24.9153	14.7759	22.7571	21.36202	7.61354	3.71741	26.55004	18.70173	12.68904	14.7759	14.6675	49.65616	10.74008	40.52773	9.97615	7.19111
85	70.49181	47.15646	46.73419	1.09895	20.30764	23.98866	11.95031	20.35952	18.35605	5.94536	2.38194	26.05914	19.95366	11.78742	11.95031	13.84455	45.02653	10.43949	38.87243	8.7983	7.61329
86	67.40233	44.21997	43.49474	1.49125	18.28335	23.18294	9.16694	17.80398	15.72703	4.52905	1.21757	25.62942	21.21774	11.01239	9.16694	12.95128	39.99519	10.08476	37.18601	7.72027	7.87871
87	64.01631	41.23497	40.10949	1.26442	15.9707	22.48052	6.56821	15.16261	13.54989	3.37216	0.20714	25.21111	22.41115	10.36871	6.56821	12.0069	34.69078	9.66882	35.44718	6.7116	7.97126
88	60.30635	38.28954	36.62246	0.57666	13.49675	21.84588	4.3175	12.53206	11.85239	2.45924	0.69608	24.77401	23.463	9.85204	4.3175	11.0408	29.24619	9.19558	33.64365	5.74911	7.91875
89	56.27658	35.47196	33.0802	0.40687	10.97107	21.22758	2.5742	10.00996	10.61217	1.77347	1.53955	24.30429	24.31557	9.453	2.5742	10.08447	23.79202	8.68062	31.7732	4.82779	7.76465

90	51.96215	32.85796	29.53598	1.50498	8.49153	20.56855	1.46327	7.67437	9.76568	1.323	2.339	23.79328	24.92396	9.16159	1.46327	9.16665	18.45493	8.14579	29.84301	3.96254	7.5498
91	47.42463	30.50249	26.05407	2.51024	6.15838	19.81889	1.0573	5.57369	9.2274	1.13941	3.06212	23.22484	25.24807	8.96805	1.0573	8.30756	13.35634	7.6164	27.87043	3.17911	7.30229
92	42.74926	28.43417	22.71041	3.21789	4.07586	18.94602	1.36783	3.73111	8.91455	1.24804	3.64139	22.57191	25.25025	8.86172	1.36783	7.52017	8.61096	7.11548	25.87772	2.49708	7.03486
93	38.04248	26.66213	19.58929	3.48478	2.34333	17.94542	2.34174	2.16096	8.77207	1.6325	4.00823	21.79662	24.89597	8.82757	2.34174	6.81184	4.3242	6.65939	23.89002	1.9152	6.74713
94	33.41518	25.18479	16.77512	3.27184	1.03869	16.83281	3.85787	0.87864	8.78791	2.22176	4.12436	20.86563	24.16331	8.84335	3.85787	6.18934	0.586	6.25507	21.9285	1.4125	6.42978
95	28.97107	23.99737	14.34164	2.62724	0.20256	15.63416	5.73161	0.1011	8.98855	2.91094	3.99751	19.7627	23.0505	8.87615	5.73161	5.6613	2.54018	5.90043	20.00864	0.96288	6.0714
96	24.79615	23.0971	12.33631	1.64226	0.16901	14.37293	7.73522	0.772	9.41867	3.59833	3.67646	18.50133	21.58297	8.88874	7.73522	5.23844	5.02198	5.58988	18.13767	0.55422	5.66446
97	20.95639	22.47731	10.76471	0.43125	0.12433	13.07086	9.62864	1.1452	10.11072	4.2077	3.22905	17.12346	19.81725	8.84556	9.62864	4.93097	6.87084	5.31854	16.31776	0.20097	5.20388
98	17.49947	22.1181	9.58875	0.86366	0.25144	11.75524	11.19575	1.2542	11.05522	4.6866	2.72358	15.68548	17.82815	8.72725	11.19575	4.74463	8.13647	5.08742	14.54705	0.06337	4.68343
99	14.45463	21.97348	8.74948	2.08156	0.8534	10.46626	12.27275	1.15389	12.18217	4.99112	2.22139	14.24598	15.69902	8.53158	12.27275	4.67896	8.89651	4.90157	12.82244	0.2064	4.0929
100	11.83015	21.9678	8.19599	3.08848	1.57393	9.25457	12.76435	0.908	13.35733	5.07725	1.77565	12.85072	13.50662	8.27696	12.76435	4.72639	9.24266	4.76689	11.14034	0.21021	3.43155
101	9.61731	22.00443	7.90456	3.82792	2.31304	8.16988	12.65135	0.57289	14.39659	4.9111	1.42808	11.52858	11.31684	7.98921	12.65135	4.87641	9.25944	4.68197	9.49739	0.07112	2.72002

Section A-4 Hip Angular Velocity Data for Participant A

	Hip Lift 1	Hip Lift 2	Hip Lift 3	Hip Lift 4	Hip Lift 5	Hip Lift 6	Hip Lift 7	Hip Lift 8	Hip Lift 9	Hip Lift 10	Hip Lift 11	Hip Lift 12	Hip Lift 13	Hip Lift 14	Hip Lift 15	Hip Lift 16	Hip Lift 17	Hip Lift 18	Hip Lift 19	Hip Lift 20	Hip Lift 21
1	5.54441	6.58135	11.01967	4.95752	3.22105	3.46683	1.31694	1.76071	5.13203	3.50258	11.032	0.91605	11.6851	4.2601	1.31694	7.79382	7.41983	0.98138	0.13773	1.13152	4.09695
2	6.43812	7.96632	11.70336	5.8451	2.26932	2.08352	1.98102	2.03205	4.67248	1.49699	11.69309	1.50804	12.14805	4.55004	1.98102	9.12032	9.03268	0.39861	0.55644	1.74035	4.78461
3	7.43899	9.3298	12.31621	6.76932	0.79158	0.51634	2.66806	2.50368	3.97748	1.01156	12.22595	2.11724	12.55079	4.64897	2.66806	10.26137	10.88962	1.86902	1.18928	2.30743	5.40443
4	8.55266	10.65162	12.89201	7.66378	1.23701	1.22659	3.44912	3.13417	3.02924	3.9282	12.66349	2.81185	12.96377	4.46808	3.44912	11.24628	13.00516	3.41997	2.08115	2.96062	6.06886
5	9.78119	11.91186	13.49109	8.53523	3.80077	3.16255	4.40145	3.88757	1.81406	7.18094	13.07058	3.6858	13.49355	3.91608	4.40145	12.14972	15.37884	5.05492	3.28009	3.84499	6.90155
6	11.12449	13.09574	14.18163	9.4775	6.86829	5.31984	5.60038	4.7633	0.32018	10.70576	13.55013	4.84609	14.27372	2.90515	5.60038	13.095	17.99764	6.79926	4.82939	5.08754	8.02032
7	12.58311	14.19101	15.02873	10.62306	10.42422	7.70524	7.10647	5.80874	1.47265	14.42601	14.23369	6.38897	15.42603	1.36297	7.10647	14.22669	20.84945	8.69232	6.76464	6.78179	9.53177
8	14.16051	15.20134	16.08891	12.10168	14.47104	10.30086	8.94782	7.10544	3.59136	18.25122	15.26464	8.38455	17.03694	0.75419	8.94782	15.69333	23.92915	10.7838	9.10082	8.9917	11.53036
9	15.86619	16.16099	17.41014	14.01174	19.00535	13.06839	11.1114	8.7387	6.04756	22.10645	16.78135	10.85979	19.12848	3.44234	11.1114	17.62238	27.23628	13.12529	11.83113	11.74599	14.0929
10	17.717	17.14936	19.02363	16.38802	23.99054	15.96685	13.5453	10.78427	8.81547	25.95888	18.8912	13.79786	21.66623	6.65778	13.5453	20.11536	30.76243	15.76794	14.9157	15.03804	17.26823
11	19.73225	18.26403	20.93262	19.19669	29.33675	18.96345	16.17816	13.29424	11.83658	29.81864	21.64024	17.14999	24.57875	10.31845	16.17816	23.24683	34.48275	18.75976	18.29391	18.82778	21.06164
12	21.92778	19.58813	23.11077	22.36573	34.91384	22.04113	18.96072	16.27425	15.04885	33.73169	24.99459	20.84586	27.78029	14.32887	18.96072	27.06226	38.36812	22.13579	21.89	23.04206	25.42013
13	24.30837	21.16043	25.52492	25.80726	40.58615	25.20556	21.87242	19.65991	18.41168	37.76564	28.84956	24.80848	31.18594	18.58992	21.87242	31.56733	42.39093	25.91359	25.63078	27.5749	30.23215
14	26.86925	22.97246	28.1437	29.40585	46.2381	28.47507	24.89642	23.31613	21.91223	41.98532	33.06312	28.96079	34.71096	23.01014	24.89642	36.71984	46.52873	30.08226	29.45196	32.29903	35.3439
15	29.59953	24.9956	30.92632	33.01413	51.78176	31.87215	28.00118	27.05928	25.55053	46.42055	37.49404	33.22832	38.26851	27.50994	28.00118	42.41414	50.75438	34.61163	33.31019	37.08663	40.60485
16	32.49209	27.20168	33.81407	36.50036	57.14246	35.41318	31.14312	30.69818	29.30925	51.04023	42.03641	37.53912	41.77972	32.02381	31.14312	48.50601	55.03524	39.45699	37.18047	41.83049	45.89594
17	35.55053	29.58073	36.73373	39.8032	62.26554	39.09801	34.28016	34.08389	33.12806	55.75711	46.63584	41.82769	45.18219	36.50459	34.28016	54.83576	59.33279	44.56818	41.0566	46.45554	51.13632
18	38.78925	32.14531	39.60796	42.94075	67.13396	42.90694	37.38269	37.14846	36.92363	60.44544	51.27593	46.04153	48.43999	40.91684	37.38269	61.26422	63.60598	49.8921	44.94492	50.91289	56.2695
19	42.22634	34.91665	42.36171	45.97671	71.78494	46.80061	40.42365	39.90557	40.63206	64.97685	55.93969	50.15448	51.55273	45.23473	40.42365	67.68131	67.8144	55.37393	48.85992	55.15903	61.23442
20	45.86397	37.90606	44.93311	48.99019	76.29343	50.73326	43.36512	42.44418	44.22498	69.26241	60.58884	54.16855	54.54126	49.43742	43.36512	74.00401	71.92402	60.9605	52.82348	59.15714	65.96259
21	49.67846	41.09249	47.29004	52.0677	80.73219	54.66466	46.16508	44.91562	47.70411	73.27046	65.16618	58.10825	57.43525	53.50991	46.16508	80.17174	75.91421	66.60147	56.85706	62.8884	70.38721
22	53.61113	44.41947	49.44836	55.28439	85.1367	58.56568	48.79754	47.50588	51.08931	77.00362	69.61373	62.01164	60.25414	57.4458	48.79754	86.14716	79.7791	72.25139	60.97831	66.35802	74.46117
23	57.58208	47.80577	51.4804	58.67185	89.48525	62.41684	51.24458	50.38178	54.40535	80.4686	73.89678	65.9242	63.00591	61.24963	51.24458	91.91483	83.52769	77.87378	65.19287	69.58478	78.15593
24	61.50853	51.16863	53.48971	62.20667	93.72017	66.20596	53.49273	53.63772	57.671	83.67751	78.01846	69.89441	65.68595	64.93636	53.49273	97.47985	87.16956	83.44244	69.4955	72.57294	81.45225
25	65.32357	54.45584	55.57071	65.8192	97.79338	69.92889	55.54161	57.26902	60.88819	86.65553	82.0099	73.96802	68.27432	68.53321	55.54161	102.8503	90.70583	88.94595	73.86674	75.3153	84.34071
26	68.9883	57.6507	57.77896	69.40348	101.6866	73.5928	57.40533	61.18079	64.03046	89.43726	85.91722	78.17138	70.74072	72.075	57.40533	108.0281	94.11183	94.38663	78.28082	77.83195	86.84652
27	72.48136	60.76661	60.1245	72.84308	105.4107	77.21861	59.09871	65.22559	67.05047	92.05828	89.78441	82.49873	73.04965	75.60265	59.09871	112.9987	97.33726	99.77263	82.70729	80.18568	89.05759
28	75.78854	63.82714	62.5888	76.04726	108.9843	80.83165	60.63518	69.24784	69.89664	94.54918	93.63219	86.9056	75.17137	79.1625	60.63518	117.7418	100.3084	105.0962	87.11202	82.45119	91.09904
29	78.88863	66.84484	65.14264	78.95992	112.4008	84.45025	62.0393	73.12503	72.53468	96.92977	97.44118	91.32388	77.09086	82.79745	62.0393	122.2368	102.9541	110.3088	91.45735	84.6563	93.08354
30	81.76958	69.8175	67.74896	81.55124	115.6108	88.07462	63.36957	76.79148	74.97378	99.20464	101.1597	95.68967	78.80716	86.54297	63.36957	126.4678	105.2233	115.3143	95.70005	86.77048	95.05097
31	84.44397	72.73362	70.36549	83.81013	118.521	91.69051	64.71293	80.23864	77.27867	101.3586	104.7227	99.95699	80.32526	90.42266	64.71293	130.4193	107.0993	119.9943	99.80168	88.74754	96.99049
32	86.96945	75.58735	72.95609	85.74699	121.0156	95.26865	66.15343	83.49574	79.53803	103.3614	108.0658	104.102	81.64738	94.4502	66.15343	134.0757	108.5997	124.2447	103.7404	90.56261	98.87354
33	89.41361	78.383	75.50912	87.4203	122.9887	98.75702	67.75568	86.60513	81.81703	105.179	111.1258	108.1073	82.77417	98.62727	67.75568	137.4225	109.7669	128.0021	107.5182	92.21918	100.6791
34	91.82483	81.13543	78.03327	88.95188	124.3754	102.0827	69.5703	89.61367	84.13033	106.792	113.8289	111.952	83.71202	102.9346	69.5703	140.4423	110.661	131.2432	111.1601	93.72778	102.3782
35	94.19644	83.86558	80.54208	90.4854	125.1697	105.1718	71.64787	92.56971	86.45444	108.2127	116.0959	115.6027	84.48765	107.3347	71.64787	143.1097	111.3473	133.9665	114.6971	95.08347	103.9328
36	96.4856	86.58533	83.03957	92.10847	125.4186	107.9881	74.04025	95.51374	88.76158	109.4827	117.8595	119.0181	85.14607	111.7723	74.04025	145.3864	111.89	136.177	118.1541	96.2647	105.3016
37	98.63504	89.29349	85.51627	93.81592	125.1885	110.5621	76.79955	98.46033	91.03884	110.6439	119.0806	122.1548	85.74243	116.1902	76.79955	147.2295	112.3478	137.8789	121.5312	97.23639	106.4483
38	100.5962	91.97701	87.96243	95.54474	124.539	112.9638	79.9764	101.3775	93.27909	111.7121	119.7602	124.973	86.3119	120.533	79.9764	148.5977	112.7753	139.0753	124.8087	97.95743	107.3391
39	102.3414	94.62171	90.38103	97.22138	123.5081	115.2638	83.61415	104.1782	95.47875	112.6706	119.9396	127.4352	86.85989	124.7513	83.61415	149.4571	113.2231	139.7692	127.9459	98.39838	107.9451
40	103.8643	97.21298	92.75964	98.79507	122.1106	117.4863	87.72707	106.7328	97.64481	113.4866	119.6818	129.5076	87.35474	128.7942	87.72707	149.7805	113.7342	139.9671	130.8895	98.57052	108.2514
41	105.1795	99.7345	95.03729	100.244	120.3566	119.6237	92.27326	108.903	99.79434	114.131	119.0485	131.1614	87.74352	132.6075	92.27326	149.547	114.3358	139.6815	133.5785	98.52842	108.2702

42	106.3196	102.1661	97.10788	101.5587	118.2694	121.6531	97.14046	110.5869	101.9311	114.5739	118.0828	132.3769	87.97108	136.1341	97.14046	148.7414	115.033	138.94	135.9464	98.34473	108.0463
43	107.3284	104.484	98.89363	102.7315	115.8949	123.5636	102.1536	111.7572	104.0056	114.774	116.7984	133.1397	87.99601	139.3203	102.1536	147.3478	115.7959	137.782	137.9296	98.08601	107.6379
44	108.2533	106.6659	100.3959	103.7623	113.3005	125.3509	107.1122	112.459	105.8913	114.6763	115.1786	133.4395	87.79728	142.1198	107.1122	145.3457	116.5674	136.2565	139.4734	97.80247	107.0969
45	109.1306	108.696	101.6627	104.6622	110.5616	127.0102	111.818	112.7847	107.4125	114.2054	113.1895	133.2716	87.37454	144.4956	111.818	142.7073	117.2699	134.4124	140.5397	97.52358	106.4524
46	109.9826	110.5673	102.7364	105.4542	107.7527	128.5271	116.0884	112.8473	108.4207	113.2653	110.8036	132.6495	86.75038	146.4165	116.0884	139.4141	117.8272	132.2924	141.1079	97.25207	105.7118
47	110.8206	112.2713	103.63	106.1648	104.9325	129.8787	119.7677	112.7663	108.8456	111.7433	108.0134	131.61	85.97353	147.855	119.7677	135.4679	118.1755	129.9274	141.1864	96.96425	104.8744
48	111.6527	113.7932	104.361	106.7958	102.1291	131.0358	122.7455	112.6613	108.6913	109.5146	104.8282	130.2145	85.10811	148.785	122.7455	130.9048	118.2715	127.3351	140.8057	96.61836	103.9407
49	112.4871	115.1154	104.9707	107.3031	99.34367	131.9639	124.9906	112.6363	108.0063	106.4572	101.2599	128.516	84.22309	149.1812	124.9906	125.7873	118.1072	124.5235	140.0235	96.16647	102.9082
50	113.3287	116.2419	105.5085	107.6211	96.57544	132.6251	126.5462	112.7506	106.864	102.4979	97.31644	126.5423	83.36926	149.0195	126.5462	120.1961	117.7039	121.4915	138.9111	95.55734	101.7644
51	114.1745	117.1985	106.0103	107.7058	93.83447	132.9804	127.4984	112.9969	105.3568	97.66461	93.02867	124.2827	82.57644	148.2803	127.4984	114.2248	117.1086	118.2317	137.5469	94.71151	100.4877
52	115.0185	118.0229	106.4866	107.5597	91.14333	132.9932	127.9405	113.2954	103.5761	92.09687	88.47019	121.7136	81.85286	146.9467	127.9405	107.9729	116.3585	114.7333	135.9988	93.52142	99.04641
53	115.8594	118.7393	106.9145	107.2268	88.52637	132.634	127.9611	113.5063	101.574	86.0237	83.75281	118.819	81.18635	145.0008	127.9611	101.5426	115.4755	110.9875	134.3185	91.89368	97.39296
54	116.7088	119.3516	107.2418	106.7614	85.98978	131.8802	127.6282	113.4496	99.36151	79.71368	79.00024	115.6087	80.55422	142.4264	127.6282	95.03561	114.4633	106.9946	132.5252	89.79972	95.47491
55	117.5918	119.8472	107.41	106.1833	83.51649	130.713	126.9677	112.9401	96.94357	73.41488	74.31592	112.1238	79.9311	139.2143	126.9677	88.54738	113.3254	102.7672	130.616	87.28939	93.24445
56	118.5333	120.2046	107.375	105.4759	81.06835	129.1137	125.9472	111.825	94.33278	67.32458	69.78094	108.4234	79.30053	135.3812	125.9472	82.16788	112.0682	98.33012	128.5684	84.44334	90.66557
57	119.5441	120.3943	107.1179	104.6146	78.59162	127.0668	124.4814	110.0145	91.53751	61.59096	65.46746	104.5733	78.65594	130.9715	124.4814	75.98457	110.7011	93.72324	126.3544	81.34287	87.71741
58	120.5972	120.3789	106.6569	103.5824	76.02971	124.5569	122.4884	107.4949	88.55705	56.30402	61.44957	100.6277	77.99564	126.0613	122.4884	70.09318	109.222	89.00448	123.9499	78.0629	84.40171
59	121.6306	120.1185	106.0453	102.3693	73.34554	121.5669	119.9304	104.3216	85.39292	51.5066	57.80495	96.62695	77.31223	120.7458	119.9304	64.59356	107.6041	84.243	121.3507	74.67367	80.75515
60	122.5537	119.5876	105.3416	100.9774	70.54102	118.0872	116.8216	100.5792	82.03311	47.21951	54.60074	92.60091	76.57851	115.1289	116.8216	59.5822	105.7713	79.50959	118.5695	71.23694	76.85969
61	123.266	118.781	104.5741	99.41401	67.66451	114.1303	113.2244	96.34169	78.43118	43.45514	51.85895	88.58165	75.75426	109.3168	113.2244	55.13202	103.6152	74.86708	115.6368	67.78746	72.82462
62	123.6819	117.7154	103.7206	97.66084	64.78406	109.7407	109.2619	91.65202	74.52088	40.2111	49.54216	84.60524	74.7986	103.4154	109.2619	51.28254	101.024	70.37577	112.5873	64.32702	68.74551
63	123.7427	116.4247	102.7196	95.66075	61.96244	104.9967	105.1372	86.54133	70.28858	37.46136	47.55827	80.70206	73.67233	97.52747	105.1372	48.03028	97.95512	66.09502	109.4531	60.84643	64.68137
64	123.429	114.9415	101.5182	93.34019	59.23375	99.99074	101.1038	81.06786	65.83009	35.14581	45.78225	76.879	72.34187	91.7459	101.1038	45.33346	94.47186	62.08389	106.2474	57.35299	60.64977
65	122.7529	113.2876	100.097	90.64888	56.58111	94.81931	97.39521	75.33952	61.32285	33.16962	44.08914	73.12561	70.78526	86.15543	97.39521	43.12456	90.74763	58.39589	102.9649	53.89158	56.64928
66	121.7497	111.4773	98.46896	87.59852	53.92901	89.57663	94.13134	69.51093	56.9403	31.40787	42.38663	69.42312	68.99943	80.83058	94.13134	41.3176	87.01736	55.07426	99.57552	50.55431	52.68868
67	120.4695	109.5332	96.66387	84.28873	51.17576	84.35175	91.26546	63.75931	52.81068	29.71867	40.63113	65.75269	67.00111	75.82578	91.26546	39.8179	83.49505	52.13864	96.0435	47.44133	48.80213
68	118.9657	107.4938	94.71163	80.87457	48.22979	79.22702	88.56424	58.25497	49.02663	27.97647	38.81984	62.09455	64.82779	71.16808	88.56424	38.53001	80.32581	49.58982	92.33587	44.60012	45.04965
69	117.2898	105.4022	92.62473	77.50706	45.0456	74.27637	85.66528	53.14287	45.64009	26.12169	36.97632	58.43056	62.52951	66.84991	85.66528	37.3638	77.54803	47.41108	88.44993	41.99638	41.50144
70	115.4871	103.2939	90.40999	74.29082	41.6554	69.56714	82.21932	48.52159	42.64542	24.17844	35.13495	54.74974	60.15683	62.82764	82.21932	36.24231	75.12273	45.57705	84.4087	39.54354	38.23253
71	113.5879	101.1916	88.07904	71.24937	38.14907	65.15798	78.1013	44.42136	39.96618	22.23766	33.3229	51.06273	57.75319	59.03948	78.1013	35.10197	72.9492	44.05368	80.26957	37.18832	35.32195
72	111.6057	99.11354	85.64771	68.32981	34.63769	61.0937	73.46033	40.79243	37.45626	20.4115	31.54263	47.39848	55.35373	55.41889	73.46033	33.89358	70.91727	42.79551	76.0966	34.97686	32.85184
73	109.5374	97.07071	83.13714	65.44534	31.21489	57.39278	68.59479	37.52444	34.92985	18.79826	29.76755	43.7994	52.98821	51.91878	68.59479	32.58083	68.92747	41.74526	71.95361	33.02407	30.89167
74	107.3678	95.0582	80.56019	62.49989	27.9409	54.04655	63.79749	34.49318	32.22927	17.46274	27.95332	40.31063	50.68384	48.51381	63.79749	31.14123	66.90764	40.84025	67.88849	31.43934	29.47287
75	105.0789	93.05289	77.91257	59.39112	24.85073	51.02119	59.24726	31.5953	29.28657	16.41917	26.06208	36.98699	48.46986	45.20576	59.24726	29.57038	64.80753	40.02094	63.93874	30.26072	28.56473
76	102.6552	91.01227	75.17979	56.02743	21.96652	48.25943	55.02065	28.76956	26.14822	15.62959	24.08813	33.8922	46.37107	42.01305	55.02065	27.8941	62.59142	39.23159	60.13179	29.4337	28.05932
77	100.0887	88.87878	72.35204	52.35982	19.30608	45.67835	51.15079	26.0075	22.947	15.05586	22.0574	31.08973	44.40106	38.96458	51.15079	26.16838	60.23101	38.41937	56.49008	28.83813	27.80872
78	97.38222	86.59899	69.42494	48.40806	16.88033	43.18317	47.6769	23.35401	19.83929	14.69141	20.0218	28.61985	42.5497	36.09009	47.6769	24.47715	57.68608	37.53236	53.03182	28.33146	27.6723
79	94.54387	84.13947	66.39566	44.24849	14.69469	40.68671	44.67368	20.87107	16.9642	14.56153	18.04993	26.49559	40.78568	33.41122	44.67368	22.9095	54.91317	36.52498	49.77014	27.78233	27.55688
80	91.5802	81.48444	63.25584	39.97689	12.75526	38.1433	42.24943	18.60855	14.44712	14.69477	16.20421	24.7034	39.06904	30.94002	42.24943	21.54308	51.89052	35.36171	46.71545	27.09051	27.42741
81	88.49846	78.62736	59.99349	35.7045	11.07484	35.55246	40.49296	16.6009	12.40012	15.07933	14.51336	23.21866	37.38028	28.68909	40.49296	20.43374	48.6328	34.02353	43.87757	26.19458	27.27684
82	85.30997	75.57373	56.60432	31.5803	9.67302	32.95293	39.3871	14.88103	10.89114	15.62705	12.97663	22.00737	35.73638	26.68091	39.3871	19.6102	45.19404	32.50534	41.26097	25.07116	27.09435
83	82.0316	72.34598	53.10255	27.80841	8.56228	30.39799	38.7449	13.4827	9.92144	16.1706	11.58832	21.02208	34.18355	24.95245	38.7449	19.07821	41.6699	30.8159	38.86161	23.72793	26.83714
84	78.67734	68.98702	49.52418	24.61013	7.73735	27.93191	38.20254	12.43846	9.42859	16.51577	10.35826	20.18926	32.77604	23.53204	38.20254	18.82366	38.17263	28.96925	36.66838	22.17529	26.42375
85	75.25584	65.5625	45.93231	22.12959	7.17419	25.58385	37.31496	11.77055	9.31908	16.50623	9.31423	19.42182	31.53917	22.43119	37.31496	18.82218	34.8084	26.98329	34.66529	20.40732	25.76601
86	71.76806	62.15724	42.41563	20.36925	6.84037	23.36958	35.687	11.47512	9.4998	16.06134	8.48528	18.63512	30.46051	21.63281	35.687	19.03486	31.61733	24.8801	32.83382	18.40648	24.80498
87	68.20345	58.8671	39.07293	19.21519	6.69714	21.30368	33.06844	11.51152	9.88033	15.17809	7.87674	17.77992	29.48625	21.09378	33.06844	19.40502	28.59215	22.6844	31.15103	16.16467	23.54771
88	64.55019	55.78809	35.98067	18.49978	6.69319	19.39976	29.41216	11.81506	10.35905	13.90327	7.45919	16.84454	28.54966	20.75343	29.41216	19.85895	25.69106	20.42368	29.58673	13.69443	22.08184
89	60.80327	52.99938	33.17675	18.04139	6.76358	17.66562	24.8958	12.30067	10.8332	12.29905	7.16988	15.85252	27.58483	20.5459	24.8958	20.31002	22.87951	18.13035	28.10776	11.04895	20.55243

90	56.97555	50.54792	30.65854	17.65705	6.83804	16.08958	19.89425	12.86155	11.21909	10.45493	6.93693	14.85408	26.53724	20.41597	19.89425	20.66233	20.16225	15.8493	26.67995	8.353	19.11776
91	53.10393	48.43958	28.39576	17.17793	6.85651	14.6402	14.92952	13.3723	11.44484	8.50629	6.70974	13.89934	25.36666	20.32446	14.92952	20.82062	17.60692	13.63951	25.27431	5.81943	17.8838
92	49.24811	46.63499	26.35398	16.49334	6.78956	13.2728	10.61339	13.70046	11.44879	6.6278	6.47088	13.02763	24.04534	20.2539	10.61339	20.69651	15.31543	11.57225	23.86804	3.71124	16.85825
93	45.48598	45.06583	24.51645	15.57949	6.64312	11.94985	7.5478	13.72693	11.19521	4.99905	6.23254	12.26033	22.55755	20.19817	7.5478	20.21099	13.37309	9.71725	22.44899	2.22506	15.97319
94	41.89827	43.6536	22.88491	14.47331	6.44902	10.64975	6.11185	13.37521	10.69041	3.75838	6.02301	11.60108	20.89951	20.15429	6.11185	19.29386	11.79848	8.13272	21.01058	1.4077	15.12812
95	38.55688	42.32656	21.47152	13.22615	6.25455	9.36786	6.28133	12.63818	9.9824	2.96944	5.86218	11.0431	19.08362	20.09305	6.28133	17.89479	10.56268	6.8448	19.55039	1.16118	14.24807
96	35.51237	41.03386	20.27821	11.88182	6.10267	8.11406	7.66578	11.57904	9.14315	2.62173	5.74349	10.57759	17.14465	19.95848	7.66578	15.99361	9.60552	5.8471	18.06561	1.31216	13.30501
97	32.78465	39.74929	19.27593	10.48519	6.02235	6.90345	9.68711	10.30313	8.22774	2.65979	5.63733	10.20202	15.1481	19.66485	9.68711	13.61919	8.84532	5.09457	16.55363	1.69651	12.29969
98	30.36968	38.46389	18.41273	9.10617	6.02786	5.75053	11.81643	8.91913	7.26454	3.00123	5.51186	9.9105	13.18699	19.12276	11.81643	10.84477	8.1615	4.51826	15.01355	2.20067	11.23592
99	28.24467	37.17101	17.64137	7.83252	6.12361	4.66678	13.68177	7.51507	6.28718	3.53052	5.35123	9.68578	11.37403	18.25252	13.68177	7.78474	7.40678	4.04015	13.44598	2.75203	10.09645
100	26.37289	35.85827	16.94097	6.71122	6.30164	3.66858	15.03267	6.14441	5.36341	4.0987	5.16372	9.49947	9.81295	17.00397	15.03267	4.58835	6.43748	3.59098	11.85282	3.29892	8.85489
101	24.71151	34.50568	16.32375	5.72297	6.54612	2.77466	15.70426	4.83522	4.58741	4.54362	4.97907	9.31204	8.57814	15.37158	15.70426	1.42983	5.19794	3.12034	10.23165	3.79691	7.49979

Appendix B

Section B-1	Discrete Relative Phase Matlab Code
Section B-2	Continues Relative Phase Matlab Code
Section B-3	Vector Coding Matlab Code

Section B-1 Discrete Relative Phase Matlab Code

```
Final_DRP_Lift1 = Y1
Final_DRP_Lift2 = Y2
Final_DRP_Lift3 = Y3
Final_DRP_Lift4 = Y4
Final_DRP_Lift5 = Y5
Final_DRP_Lift6 = Y6
Final_DRP_Lift7 = Y7
Final_DRP_Lift8 = Y8
Final_DRP_Lift9 = Y9
Final_DRP_Lift10 = Y10
Final_DRP_Lift11 = Y11
Final_DRP_Lift12 = Y12
Final_DRP_Lift13 = Y13
Final_DRP_Lift14 = Y14
Final_DRP_Lift15 = Y15
Final_DRP_Lift16 = Y16
Final_DRP_Lift17 = Y17
Final_DRP_Lift18 = Y18
Final_DRP_Lift19 = Y19
Final_DRP_Lift20 = Y20
Final_DRP_Lift21 = Y21

function createfigure(X1, Y1, Y2, Y3, Y4, Y5, Y6, Y7, Y8, Y9, Y10, Y11, Y12, Y13, Y14, Y15, Y16, Y17, Y18, Y19, Y20, Y21)


% Create figure
figure('OuterPosition',[31 -5 1920 1056]);

% Create subplot
subplot1 = subplot(7,3,1);
hold(subplot1,'on');
% Create plot
plot(X1,Y1);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 1 - Subject A');
% X&Y axis limits
xlim(subplot1,[0 101]);
ylim(subplot1,[0 360]);
box(subplot1,'on');


% Create subplot
subplot2 = subplot(7,3,2);
hold(subplot2,'on');
% Create plot
plot(X1,Y2);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 2 - Subject A');
% X&Y axis limits
xlim(subplot2,[0 101]);
ylim(subplot2,[0 360]);
box(subplot2,'on');


% Create subplot
subplot3 = subplot(7,3,3);
hold(subplot3,'on');
% Create plot
plot(X1,Y3);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
```

```
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 3 - Subject A');
% X&Y axis limits
xlim(subplot3,[0 101]);
ylim(subplot3,[0 360]);
box(subplot3,'on');


% Create subplot
subplot4 = subplot(7,3,4);
hold(subplot4,'on');
% Create plot
plot(X1,Y4);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 4 - Subject A');
% X&Y axis limits
xlim(subplot4,[0 101]);
ylim(subplot4,[0 360]);
box(subplot4,'on');


% Create subplot
subplot5 = subplot(7,3,5);
hold(subplot5,'on');
% Create plot
plot(X1,Y5);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 5 - Subject A');
% X&Y axis limits
xlim(subplot5,[0 101]);
ylim(subplot5,[0 360]);
box(subplot5,'on');


% Create subplot
subplot6 = subplot(7,3,6);
hold(subplot6,'on');
% Create plot
plot(X1,Y6);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 6 - Subject A');
% X&Y axis limits
xlim(subplot6,[0 101]);
ylim(subplot6,[0 360]);
box(subplot6,'on');


% Create subplot
subplot7 = subplot(7,3,7);
hold(subplot7,'on');
% Create plot
plot(X1,Y7);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 7 - Subject A');
% X&Y axis limits
xlim(subplot7,[0 101]);
```

```
ylim(subplot7,[0 360]);
box(subplot7,'on');


% Create subplot
subplot8 = subplot(7,3,8);
hold(subplot8,'on');
% Create plot
plot(X1,Y8);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 8 - Subject A');
% X&Y axis limits
xlim(subplot8,[0 101]);
ylim(subplot8,[0 360]);
box(subplot8,'on');


% Create subplot
subplot9 = subplot(7,3,9);
hold(subplot9,'on');
% Create plot
plot(X1,Y9);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 9 - Subject A');
% X&Y axis limits
xlim(subplot9,[0 101]);
ylim(subplot9,[0 360]);
box(subplot9,'on');


% Create subplot
subplot10 = subplot(7,3,10);
hold(subplot10,'on');
% Create plot
plot(X1,Y10);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 10 - Subject A');
% X&Y axis limits
xlim(subplot10,[0 101]);
ylim(subplot10,[0 360]);
box(subplot10,'on');


% Create subplot
subplot11 = subplot(7,3,11);
hold(subplot11,'on');
% Create plot
plot(X1,Y11);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 11 - Subject A');
% X&Y axis limits
xlim(subplot11,[0 101]);
ylim(subplot11,[0 360]);
box(subplot11,'on');


% Create subplot
```

```
subplot12 = subplot(7,3,12);
hold(subplot12,'on');
% Create plot
plot(X1,Y12);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 12 - Subject A');
% X&Y axis limits
xlim(subplot12,[0 101]);
ylim(subplot12,[0 360]);
box(subplot12,'on');


% Create subplot
subplot13 = subplot(7,3,13);
hold(subplot13,'on');
% Create plot
plot(X1,Y13);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 13 - Subject A');
% X&Y axis limits
xlim(subplot13,[0 101]);
ylim(subplot13,[0 360]);
box(subplot13,'on');


% Create subplot
subplot14 = subplot(7,3,14);
hold(subplot14,'on');
% Create plot
plot(X1,Y14);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 14 - Subject A');
% X&Y axis limits
xlim(subplot14,[0 101]);
ylim(subplot14,[0 360]);
box(subplot14,'on');


% Create subplot
subplot15 = subplot(7,3,15);
hold(subplot15,'on');
% Create plot
plot(X1,Y15);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 15 - Subject A');
% X&Y axis limits
xlim(subplot15,[0 101]);
ylim(subplot15,[0 360]);
box(subplot15,'on');


% Create subplot
subplot16 = subplot(7,3,16);
hold(subplot16,'on');
% Create plot
plot(X1,Y16);
% Create ylabel
```

```
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 16 - Subject A');
% X&Y axis limits
xlim(subplot16,[0 101]);
ylim(subplot16,[0 360]);
box(subplot16,'on');


% Create subplot
subplot17 = subplot(7,3,17);
hold(subplot17,'on');
% Create plot
plot(X1,Y17);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 17 - Subject A');
% X&Y axis limits
xlim(subplot17,[0 101]);
ylim(subplot17,[0 360]);
box(subplot17,'on');


% Create subplot
subplot18 = subplot(7,3,18);
hold(subplot18,'on');
% Create plot
plot(X1,Y18);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 18 - Subject A');
% X&Y axis limits
xlim(subplot18,[0 101]);
ylim(subplot18,[0 360]);
box(subplot18,'on');


% Create subplot
subplot19 = subplot(7,3,19);
hold(subplot19,'on');
% Create plot
plot(X1,Y19);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 19 - Subject A');
% X&Y axis limits
xlim(subplot19,[0 101]);
ylim(subplot19,[0 360]);
box(subplot19,'on');


% Create subplot
subplot20 = subplot(7,3,20);
hold(subplot20,'on');
% Create plot
plot(X1,Y20);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 20 - Subject A');
```

```
% X&Y axis limits
xlim(subplot20,[0 101]);
ylim(subplot20,[0 360]);
box(subplot20,'on');


% Create subplot
subplot21 = subplot(7,3,21);
hold(subplot21,'on');
% Create plot
plot(X1,Y21);
% Create ylabel
ylabel('DRP (Degrees)');
% Create xlabel
xlabel('Lifting Cycle %');
% Create title
title('DRP - Lift 21 - Subject A');
% X&Y axis limits
xlim(subplot21,[0 101]);
ylim(subplot21,[0 360]);
box(subplot21,'on');
```

Section B-2 Continues Relative Phase Matlab Code

```
Lifting_Cycle_% = X1
Final_CRP_Lift1 = Y1
Final_CRP_Lift2 = Y2
Final_CRP_Lift3 = Y3
Final_CRP_Lift4 = Y4
Final_CRP_Lift5 = Y5
Final_CRP_Lift6 = Y6
Final_CRP_Lift7 = Y7
Final_CRP_Lift8 = Y8
Final_CRP_Lift9 = Y9
Final_CRP_Lift10 = Y10
Final_CRP_Lift11 = Y11
Final_CRP_Lift12 = Y12
Final_CRP_Lift13 = Y13
Final_CRP_Lift14 = Y14
Final_CRP_Lift15 = Y15
Final_CRP_Lift16 = Y16
Final_CRP_Lift17 = Y17
Final_CRP_Lift18 = Y18
Final_CRP_Lift19 = Y19
Final_CRP_Lift20 = Y20
Final_CRP_Lift21 = Y21

function createfigure(X1, Y1, Y2, Y3, Y4, Y5, Y6, Y7, Y8, Y9, Y10, Y11, Y12, Y13, Y14, Y15, Y16, Y17, Y18, Y19, Y20, Y21)


% Create figure
figure('OuterPosition',[31 -5 1920 1056]);

% Create subplot
subplot1 = subplot(7,3,1);
hold(subplot1,'on');
% Create plot
plot(X1,Y1);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 1 - Subject A');
% X&Y axis limits
xlim(subplot1,[0 105]);
ylim(subplot1,[-1 1.5]);
box(subplot1,'on');


% Create subplot
subplot2 = subplot(7,3,4);
hold(subplot2,'on');
% Create plot
plot(X1,Y2);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 2 - Subject A');
% X&Y axis limits
xlim(subplot2,[0 105]);
ylim(subplot2,[-1 1.5]);
box(subplot2,'on');


% Create subplot
subplot3 = subplot(7,3,7);
hold(subplot3,'on');
% Create plot
plot(X1,Y3);
% Create ylabel
ylabel('CRP (°)');
```

```
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 3 - Subject A');
% X&Y axis limits
xlim(subplot3,[0 105]);
ylim(subplot3,[-1 1.5]);
box(subplot3,'on');


% Create subplot
subplot4 = subplot(7,3,10);
hold(subplot4,'on');

% Create plot
plot(X1,Y4);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 4 - Subject A');
% X&Y axis limits
xlim(subplot4,[0 105]);
ylim(subplot4,[-1 1.5]);
box(subplot4,'on');


% Create subplot
subplot5 = subplot(7,3,13);
hold(subplot5,'on');
% Create plot
plot(X1,Y5);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 5 - Subject A');
% X&Y axis limits
xlim(subplot5,[0 105]);
ylim(subplot5,[-1 1.5]);
box(subplot5,'on');


% Create subplot
subplot6 = subplot(7,3,16);
hold(subplot6,'on');
% Create plot
plot(X1,Y6);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 6 - Subject A');
% X&Y axis limits
xlim(subplot6,[0 105]);
ylim(subplot6,[-1 1.5]);
box(subplot6,'on');


% Create subplot
subplot7 = subplot(7,3,19);
hold(subplot7,'on');
% Create plot
plot(X1,Y7);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 7 - Subject A');
```

```
% X&Y axis limits
xlim(subplot7,[0 105]);
ylim(subplot7,[-1 1.5]);
box(subplot7,'on');


% Create subplot
subplot8 = subplot(7,3,2);
hold(subplot8,'on');
% Create plot
plot(X1,Y8);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 8 - Subject A');
% X&Y axis limits
xlim(subplot8,[0 105]);
ylim(subplot8,[-1 1.5]);
box(subplot8,'on');


% Create subplot
subplot9 = subplot(7,3,5);
hold(subplot9,'on');
% Create plot
plot(X1,Y9);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 9 - Subject A');
% X&Y axis limits
xlim(subplot9,[0 105]);
ylim(subplot9,[-1 1.5]);
box(subplot9,'on');


% Create subplot
subplot10 = subplot(7,3,8);
hold(subplot10,'on');
% Create plot
plot(X1,Y10);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 10 - Subject A');
% X&Y axis limits
xlim(subplot10,[0 105]);
ylim(subplot10,[-1 1.5]);
box(subplot10,'on');


% Create subplot
subplot11 = subplot(7,3,11);
hold(subplot11,'on');
% Create plot
plot(X1,Y11);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 11 - Subject A');
% X&Y axis limits
xlim(subplot11,[0 105]);
ylim(subplot11,[-1 1.5]);
box(subplot11,'on');
```

```
% Create subplot
subplot12 = subplot(7,3,14);
hold(subplot12,'on');
% Create plot
plot(X1,Y12);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 12 - Subject A');
% X&Y axis limits
xlim(subplot12,[0 105]);
ylim(subplot12,[-1 1.5]);
box(subplot12,'on');


% Create subplot
subplot13 = subplot(7,3,17);
hold(subplot13,'on');
% Create plot
plot(X1,Y13);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 13 - Subject A');
% X&Y axis limits
xlim(subplot13,[0 105]);
ylim(subplot13,[-1 1.5]);
box(subplot13,'on');


% Create subplot
subplot14 = subplot(7,3,20);
hold(subplot14,'on');
% Create plot
plot(X1,Y14);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 14 - Subject A');
% X&Y axis limits
xlim(subplot14,[0 105]);
ylim(subplot14,[-1 1.5]);
box(subplot14,'on');


% Create subplot
subplot15 = subplot(7,3,3);
hold(subplot15,'on');
% Create plot
plot(X1,Y15);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 15 - Subject A');
% X&Y axis limits
xlim(subplot15,[0 105]);
ylim(subplot15,[-1 1.5]);
box(subplot15,'on');


% Create subplot
subplot16 = subplot(7,3,6);
hold(subplot16,'on');
% Create plot
```

```
plot(X1,Y16);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 16 - Subject A');
% X&Y axis limits
xlim(subplot16,[0 105]);
ylim(subplot16,[-1 1.5]);
box(subplot16,'on');


% Create subplot
subplot17 = subplot(7,3,9);
hold(subplot17,'on');
% Create plot
plot(X1,Y17);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 17 - Subject A');
% X&Y axis limits
xlim(subplot17,[0 105]);
ylim(subplot17,[-1 1.5]);
box(subplot17,'on');


% Create subplot
subplot18 = subplot(7,3,12);
hold(subplot18,'on');
% Create plot
plot(X1,Y18);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 18 - Subject A');
% X&Y axis limits
xlim(subplot18,[0 105]);
ylim(subplot18,[-1 1.5]);
box(subplot18,'on');


% Create subplot
subplot19 = subplot(7,3,15);
hold(subplot19,'on');
% Create plot
plot(X1,Y19);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 19 - Subject A');
% X&Y axis limits
xlim(subplot19,[0 105]);
ylim(subplot19,[-1 1.5]);
box(subplot19,'on');


% Create subplot
subplot20 = subplot(7,3,18);
hold(subplot20,'on');
% Create plot
plot(X1,Y20);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
```

```
% Create title
title('CRP - Lift 20 - Subject A');
% X&Y axis limits
xlim(subplot20,[0 105]);
ylim(subplot20,[-1 1.5]);
box(subplot20,'on');


% Create subplot
subplot21 = subplot(7,3,21);
hold(subplot21,'on');
% Create plot
plot(X1,Y21);
% Create ylabel
ylabel('CRP (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('CRP - Lift 21 - Subject A');
% X&Y axis limits
xlim(subplot21,[0 105]);
ylim(subplot21,[-1 1.5]);
box(subplot21,'on');
```

Section B-3 Vector Coding Matlab Code

```
Final_Vector_Coding_Lift1 = Y1
Final_Vector_Coding_Lift2 = Y2
Final_Vector_Coding_Lift3 = Y3
Final_Vector_Coding_Lift4 = Y4
Final_Vector_Coding_Lift5 = Y5
Final_Vector_Coding_Lift6 = Y6
Final_Vector_Coding_Lift7 = Y7
Final_Vector_Coding_Lift8 = Y8
Final_Vector_Coding_Lift9 = Y9
Final_Vector_Coding_Lift10 = Y10
Final_Vector_Coding_Lift11 = Y11
Final_Vector_Coding_Lift12 = Y12
Final_Vector_Coding_Lift13 = Y13
Final_Vector_Coding_Lift14 = Y14
Final_Vector_Coding_Lift15 = Y15
Final_Vector_Coding_Lift16 = Y16
Final_Vector_Coding_Lift17 = Y17
Final_Vector_Coding_Lift18 = Y18
Final_Vector_Coding_Lift19 = Y19
Final_Vector_Coding_Lift20 = Y20
Final_Vector_Coding_Lift21 = Y21

function createfigure(X1, Y1, Y2, Y3, Y4, Y5, Y6, Y7, Y8, Y9, Y10, Y11, Y12, Y13, Y14, Y15, Y16, Y17, Y18, Y19, Y20, Y21)

% Create figure
figure('OuterPosition',[31 -5 1920 1056]);

% Create subplot
subplot1 = subplot(7,3,1);
hold(subplot1,'on');
% Create plot
plot(X1,Y1);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 1 - Subject A');
% X&Y axis limits
xlim(subplot1,[0 105]);
ylim(subplot1,[-2 2]);
box(subplot1,'on');


% Create subplot
subplot2 = subplot(7,3,4);
hold(subplot2,'on');
% Create plot
plot(X1,Y2);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 2 - Subject A');
% X&Y axis limits
xlim(subplot2,[0 105]);
ylim(subplot2,[-2 2]);
box(subplot2,'on');


% Create subplot
subplot3 = subplot(7,3,7);
hold(subplot3,'on');
% Create plot
plot(X1,Y3);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
```

```
% Create title
title('Lift 3 - Subject A');
% X&Y axis limits
xlim(subplot3,[0 105]);
ylim(subplot3,[-2 2]);
box(subplot3,'on');


% Create subplot
subplot4 = subplot(7,3,10);
hold(subplot4,'on');
% Create plot
plot(X1,Y4);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 4 - Subject A');
% X&Y axis limits
xlim(subplot4,[0 105]);
ylim(subplot4,[-2 2]);
box(subplot4,'on');


% Create subplot
subplot5 = subplot(7,3,13);
hold(subplot5,'on');
% Create plot
plot(X1,Y5);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 5 - Subject A');
% X&Y axis limits
xlim(subplot5,[0 105]);
ylim(subplot5,[-2 2]);
box(subplot5,'on');


% Create subplot
subplot6 = subplot(7,3,16);
hold(subplot6,'on');
% Create plot
plot(X1,Y6);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 6 - Subject A');
% X&Y axis limits
xlim(subplot6,[0 105]);
ylim(subplot6,[-2 2]);
box(subplot6,'on');


% Create subplot
subplot7 = subplot(7,3,19);
hold(subplot7,'on');
% Create plot
plot(X1,Y7);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 7 - Subject A');
% X&Y axis limits
xlim(subplot7,[0 105]);
ylim(subplot7,[-2 2]);
```

```
box(subplot7,'on');


% Create subplot
subplot8 = subplot(7,3,2);
hold(subplot8,'on');
% Create plot
plot(X1,Y8);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 8 - Subject A');
% X&Y axis limits
xlim(subplot8,[0 105]);
ylim(subplot8,[-2 2]);
box(subplot8,'on');


% Create subplot
subplot9 = subplot(7,3,5);
hold(subplot9,'on');
% Create plot
plot(X1,Y9);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 9 - Subject A');
% X&Y axis limits
xlim(subplot9,[0 105]);
ylim(subplot9,[-2 2]);
box(subplot9,'on');


% Create subplot
subplot10 = subplot(7,3,8);
hold(subplot10,'on');
% Create plot
plot(X1,Y10);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 10 - Subject A');
% X&Y axis limits
xlim(subplot10,[0 105]);
ylim(subplot10,[-2 2]);
box(subplot10,'on');


% Create subplot
subplot11 = subplot(7,3,11);
hold(subplot11,'on');
% Create plot
plot(X1,Y11);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 11 - Subject A');
% X&Y axis limits
xlim(subplot11,[0 105]);
ylim(subplot11,[-2 2]);
box(subplot11,'on');


% Create subplot
subplot12 = subplot(7,3,14);
```

```
hold(subplot12,'on');
% Create plot
plot(X1,Y12);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 12 - Subject A');
% X&Y axis limits
xlim(subplot12,[0 105]);
ylim(subplot12,[-2 2]);
box(subplot12,'on');


% Create subplot
subplot13 = subplot(7,3,17);
hold(subplot13,'on');
% Create plot
plot(X1,Y13);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 13 - Subject A');
% X&Y axis limits
xlim(subplot13,[0 105]);
ylim(subplot13,[-2 2]);
box(subplot13,'on');


% Create subplot
subplot14 = subplot(7,3,20);
hold(subplot14,'on');
% Create plot
plot(X1,Y14);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 14 - Subject A');
% X&Y axis limits
xlim(subplot14,[0 105]);
ylim(subplot14,[-2 2]);
box(subplot14,'on');


% Create subplot
subplot15 = subplot(7,3,3);
hold(subplot15,'on');
% Create plot
plot(X1,Y15);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 15 - Subject A');
% X&Y axis limits
xlim(subplot15,[0 105]);
ylim(subplot15,[-2 2]);
box(subplot15,'on');


% Create subplot
subplot16 = subplot(7,3,6);
hold(subplot16,'on');
% Create plot
plot(X1,Y16);
% Create ylabel
ylabel('\gamma (°)');
```

```
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 16 - Subject A');
% X&Y axis limits
xlim(subplot16,[0 105]);
ylim(subplot16,[-2 2]);
box(subplot16,'on');


% Create subplot
subplot17 = subplot(7,3,9);
hold(subplot17,'on');
% Create plot
plot(X1,Y17);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 17 - Subject A');
% X&Y axis limits
xlim(subplot17,[0 105]);
ylim(subplot17,[-2 2]);
box(subplot17,'on');


% Create subplot
subplot18 = subplot(7,3,12);
hold(subplot18,'on');
% Create plot
plot(X1,Y18);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 18 - Subject A');
% X&Y axis limits
xlim(subplot18,[0 105]);
ylim(subplot18,[-2 2]);
box(subplot18,'on');


% Create subplot
subplot19 = subplot(7,3,15);
hold(subplot19,'on');
% Create plot
plot(X1,Y19);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 19 - Subject A');
% X&Y axis limits
xlim(subplot19,[0 105]);
ylim(subplot19,[-2 2]);
box(subplot19,'on');


% Create subplot
subplot20 = subplot(7,3,18);
hold(subplot20,'on');
% Create plot
plot(X1,Y20);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 20 - Subject A');
% X&Y axis limits
```

```
xlim(subplot20,[0 105]);
ylim(subplot20,[-2 2]);
box(subplot20,'on');


% Create subplot
subplot21 = subplot(7,3,21);
hold(subplot21,'on');
% Create plot
plot(X1,Y21);
% Create ylabel
ylabel('\gamma (°)');
% Create xlabel
xlabel('Lifting Cycle (%)');
% Create title
title('Lift 21 - Subject A');
% X&Y axis limits
xlim(subplot21,[0 105]);
ylim(subplot21,[-2 2]);
box(subplot21,'on');
```

References

[1] H. Haken, J. S. Kelso, and H. Bunz, "A Theoretical Model of Phase Transitions in Human Hand Movements," *Biological Cybernetics,* vol. 51, no. 5, pp. 347-356, 1985.

[2] J. Kelso, "Phase transitions and critical behavior in human bimanual coordination," *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology,* vol. 246, no. 6, pp. R1000-R1004, 1984.

[3] J. Scott Kelso, K. G. Holt, P. Rubin, and P. N. Kugler, "Patterns of Human Interlimb Coordination Emerge from the Properties of Non-linear, Limit Cycle Oscillatory Processes: Theory and Data," *Journal of Motor Behavior,* vol. 13, no. 4, pp. 226-261, 1981.

[4] J. Hamill, R. E. van Emmerik, B. C. Heiderscheit, and L. Li, "A dynamical systems approach to lower extremity running injuries," *Clinical Biomechanics,* vol. 14, no. 5, pp. 297-308, 1999.

[5] N. Stergiou, J. L. Jensen, B. T. Bates, S. D. Scholten, and G. Tzetzis, "A dynamical systems investigation of lower extremity coordination during running over obstacles," *Clinical Biomechanics,* vol. 16, no. 3, pp. 213-221, 2001.

[6] C. Lamoth, P. J. Beek, and O. G. Meijer, "Pelvis–thorax coordination in the transverse plane during gait," *Gait and Posture,* vol. 16, no. 2, pp. 101-114, 2002.

[7] R. E. Van Emmerik, R. C. Wagenaar, A. Winogrodzka, and E. C. Wolters, "Identification of Axial Rigidity During Locomotion in Parkinson Disease," *Archives of Physical Medicine and Rehabilitation,* vol. 80, no. 2, pp. 186-191, 1999.

[8] R. E. A. van Emmerik and R. Wagenaar, "Effects of Walking Velocity on Relative Phase Dynamics in the Trunk in Human Walking," *Journal of Biomechanics,* vol. 29, no. 9, pp. 1175-1184, 1996.

[9] R. Wagenaar and W. Beek, "Hemiplegic Gait: A Kinematic Analysis Using Walking Speed as a Basis," *Journal of Biomechanics,* vol. 25, no. 9, pp. 1007-1015, 1992.

[10] R. Wagenaar and R. Van Emmerik, "Resonant frequencies of arms and legs identify different walking patterns," *Journal of Biomechanics,* vol. 33, no. 7, pp. 853-861, 2000.

[11] R. C. Wagenaar and R. E. van Emmerik, "Dynamics of pathological gait," *Human Movement Science,* vol. 13, no. 3-4, pp. 441-471, 1994.

[12] M. LaFiandra, R. C. Wagenaar, K. Holt, and J. Obusek, "How do load carriage and walking speed influence trunk coordination and stride parameters?," *Journal of Biomechanics,* vol. 36, no. 1, pp. 87-95, 2003.

[13] L. Li, E. C. van den Bogert, G. E. Caldwell, R. E. van Emmerik, and J. Hamill, "Coordination patterns of walking and running at similar speed and stride frequency," *Human Movement Science,* vol. 18, no. 1, pp. 67-85, 1999.

[14] R. Burgess-Limerick, B. Abernethy, and R. J. Neal, "Relative Phase Quantifies Interjoint Coordination," *Journal of Biomechanics,* vol. 26, no. 1, pp. 91-94, 1993.

[15] J. E. Clark and S. J. Phillips, "A Longitudinal Study of Intralimb Coordination in the First Year of Independent Walking: A Dynamical Systems Analysis," *Child Development,* vol. 64, no. 4, pp. 1143-1157, 1993.

[16] M. J. Kurz and N. Stergiou, "Effect of normalization and phase angle calculations on continuous relative phase," *Journal of Biomechanics,* vol. 35, no. 3, pp. 369-374, 2002.

[17] B. T. Peters, J. M. Haddad, B. C. Heiderscheit, R. E. Van Emmerik, and J. Hamill, "Limitations in the use and interpretation of continuous relative phase," *Journal of Biomechanics,* vol. 36, no. 2, pp. 271-274, 2003.

[18] W. C. Whiting and R. F. Zernicke, "Correlation of Movement Patterns via Pattern Recognition," *Journal of Motor Behavior,* vol. 14, no. 2, pp. 135-142, 1982.

[19] C. Hershler and M. Milner, "Angle-Angle Diagrams in Above-Knee Amputee and Cerebral alsy Gait," *American Journal of Physical Medicine,* vol. 59, no. 4, pp. 165-183, 1980.

[20] W. Sparrow, E. Donovan, R. Van Emmerik, and E. Barry, "Using Relative Motion Plots to Measure Changes in Intra-Limb and Inter-Limb Coordination," *Journal of Motor Behavior,* vol. 19, no. 1, pp. 115-129, 1987.

[21] D. Tepavac and E. C. Field-Fote, "Vector Coding: A Technique for Quantification of Intersegmental Coupling in Multicyclic Behaviors," *Journal of Applied Biomechanics,* vol. 17, no. 3, pp. 259-270, 2001.

[22] J. Hamill, J. M. Haddad, and W. J. McDermott, "Issues in Quantifying Variability From a Dynamical Systems Perspective," *Journal of Applied Biomechanics,* vol. 16, no. 4, pp. 407-418, 2000.

[23] B. C. Heiderscheit, J. Hamill, and R. E. van Emmerik, "Variability of Stride Characteristics and Joint Coordination Among Individuals with Unilateral Patellofemoral Pain," *Journal of Applied Biomechanics,* vol. 18, no. 2, pp. 110-121, 2002.

[24] R. Shiavi and P. Griffin, "Representing and clustering electromyographic gait patterns with multivariate techniques," *Medical and Biological Engineering and Computing,* vol. 19, no. 5, pp. 605-611, 1981.

[25] M. Wootten, M. Kadaba, and G. Cochran, "Dynamic Electromyography. I. Numerical Representation Using Principal Component Analysis," *Journal of Orthopaedic Research,* vol. 8, no. 2, pp. 247-258, 1990.

[26] S. Yamamoto, Y. Suto, H. Kawamura, T. Hashizume, S. Kakurai, and S. Sugahara, "Quantitative Gait Evaluation of Hip Diseases Using Principal

Component Analysis," *Journal of Biomechanics,* vol. 16, no. 9, pp. 717-726, 1983.

[27] S. J. Olney, M. P. Griffin, and I. D. McBride, "Multivariate Examination of Data From Gait Analysis of Persons with Stroke," *Physical Therapy,* vol. 78, no. 8, pp. 814-828, 1998.

[28] H. Sadeghi, P. Allard, and M. Duhaime, "Functional gait asymmetry in able-bodied subjects," *Human Movement Science,* vol. 16, no. 2-3, pp. 243-258, 1997.

[29] K. J. Deluzio, U. P. Wyss, P. A. Costigan, C. Sorbie, and B. Zee, "Gait assessment in unicompartmental knee arthroplasty patients: Principal component modelling of gait waveforms and clinical status," *Human Movement Science,* vol. 18, no. 5, pp. 701-711, 1999.

[30] K. J. Deluzio, U. P. Wyss, B. Zee, P. A. Costigan, and C. Sorbie, "Principal component models of knee kinematics and kinetics: Normal vs. pathological gait patterns," *Human Movement Science,* vol. 16, no. 2, pp. 201-218, 1997.

[31] H. M. Reynolds and R. P. Hubbard, "Anatomical Frames of Reference and Biomechanics," *Human Factors,* vol. 22, no. 2, pp. 171-176, 1980.

[32] M. G. Boocock, G. A. Mawston, and S. Taylor, "Age-related differences do affect postural kinematics and joint kinetics during repetitive lifting," *Clinical Biomechanics,* vol. 30, no. 2, pp. 136-143, 2015.

[33] J. J. Jeka and J. Kelso, "Manipulating Symmetry in the Coordination Dynamics of Human Movement," *Journal of Experimental Psychology: Human Perception and Performance,* vol. 21, no. 2, p. 360, 1995.

[34] P. F. Lamb and M. Stöckl, "On the use of continuous relative phase: Review of current approaches and outline for a new standard," *Clinical Biomechanics,* vol. 29, no. 5, pp. 484-493, 2014.

[35] G. Robertson, G. Caldwell, J. Hamill, G. Kamen, and S. Whittlesey, *Research Methods in Biomechanics*, Second ed. Human Kinetics, 2013.

[36] K. Davids, S. Bennett, and K. M. Newell, *Movement system variability*. Human kinetics, 2006.

[37] J. Hamill, J. M. Haddad, and W. J. McDermott, "Issues in Quantifying Variability From a Dynamical Systems Perspective," *Journal of Applied Biomechanics,* vol. 16, no. 4, p. 407, 2000.

[38] N. I. Fisher, T. Lewis, and B. J. Embleton, *Statistical analysis of spherical data*. Cambridge University Press, 1993.

[39] E. Batschelet, *Circular Statistics in Biology*. New York: Academic Press, 1981.

[40] T. Chau, "A review of analytical techniques for gait data. Part 1: fuzzy, statistical and fractal methods," *Gait and Posture,* vol. 13, no. 1, pp. 49-66, 2001/02/01/ 2001.

[41] I. J. Pinter, R. Van Swigchem, A. K. van Soest, and L. A. Rozendaal, "The Dynamics of Postural Sway Cannot Be Captured Using a One-segment Inverted Pendulum Model: A PCA on Segment Rotations During Unperturbed Stance," *Journal of Neurophysiology,* vol. 100, no. 6, pp. 3197-3208, 2008.

[42] A. Muniz and J. Nadal, "Application of principal component analysis in vertical ground reaction force to discriminate normal and abnormal gait," *Gait and Posture,* vol. 29, no. 1, pp. 31-35, 2009.

[43] S. C. Landry, K. A. McKean, C. L. Hubley-Kozey, W. D. Stanish, and K. J. Deluzio, "Knee biomechanics of moderate OA patients measured during gait at a self-selected and fast walking speed," *Journal of Biomechanics,* vol. 40, no. 8, pp. 1754-1761, 2007.

[44] M. Wootten, M. Kadaba, and G. Cochran, "Dynamic Electromyography. II. Normal Patterns During Gait," *Journal of Orthopaedic Research,* vol. 8, no. 2, pp. 259-265, 1990.

[45] M. A. Perez and M. A. Nussbaum, "Principal components analysis as an evaluation and classification tool for lower torso sEMG data," *Journal of Biomechanics,* vol. 36, no. 8, pp. 1225-1229, 2003.

[46] C. Hubley-Kozey, K. Deluzio, S. Landry, J. McNutt, and W. Stanish, "Neuromuscular alterations during walking in persons with moderate knee osteoarthritis," *Journal of Electromyography and Kinesiology,* vol. 16, no. 4, pp. 365-378, 2006.

[47] J. E. Jackson, *A User's Guide to Principal Components*. John Wiley & Sons, 2005.