Reliability assessment of torque measures during a unilateral pressing movement.

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Abstract

The context for this project was that a perceived overemphasis on conventional flat bench press training could be interfering with the 'natural' shoulder girdle functional movement patterns and, consequently influencing performance and injury susceptibility. The width of the conventional flat bench press exercise can obstruct and restrict the scapulae movements, potentially leading to compromised shoulder girdle function. This project sought to establish the reliability of assessing pressing strength with a novel isokinetic strength task with two seat-back conditions. OBJECTIVES: 1) To assess the reliability of torque measurements obtained during a novel unilateral chest press movement; and 2) observe the effect of a narrow (uninhibited scapula) seat-back on torque-angle profiles. METHODS: Twenty participants performed maximal effort (3 sets of 5 reps) unilateral pressing movement repetitions using an Isokinetic Dynamometer with a modified Lever arm attachment. Both arms were tested under two movement conditions (a narrow bench back, MOD; and a standard width bench back, STD) across three testing sessions. Reliability was determined using intraclass correlation coefficients (ICCs). RESULTS: Measures of peak torque and total work were measured reliably (ICCs all >0.68) both eccentrically and concentrically with two testing sessions using a novel unilateral pressing motion. There was no difference evident between movement conditions for any test measure (all p>0.078). CONCLUSIONS: Strength (torque) can be reliably measured in a full range pressing motion. This reliability permits future studies to explore the effect of different training intervention on eccentric and concentric shoulder strength. The results also indicate that participants can safely test through a full pressing range, which may benefit activities that involve full horizontal abduction under load.
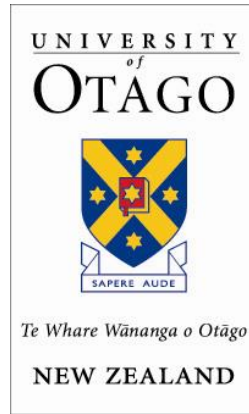
Declaration Concerning Thesis Presented for the Degree of

Master of Physical Education

I, Brett Harris, of 590 Springvale RD, Alexandra, Otago 9393,

solemnly and sincerely declare, in relation to the thesis entitled:

Reliability assessment of torque measures during a unilateral pressing movement.

(a) That work was done by me, personally

and   (b) *The* material has not previously been accepted in whole, or in part, for any other degree or diploma

Signed…………………………………………... Date……………

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List of Abbreviations

°PT: *Angle of peak torque*

1-RM: *One repetition maximum*

95% CI: *95 percent confidence intervals*

ANOVA: *Analysis of variance*

CON: *Concentric*

CSA: *Cross-sectional area*

ECC: *Eccentric*

EIMD: *Exercise-induced muscle damage*

EMG*: Electromyography*

END: *End of rep (arm fully extended)*

GHJ: *Glenohumeral joint*

ICC: *Intraclass correlation coefficient*

IW: *Work of initial 5° range-of-motion*

MEAN: *Mean of three sets*

MOD: *Narrow seat-back*

MTU: *Musculotendinous unit*

PEAK: *Highest recorded measure of three sets*

PT: *Peak torque*

ROM: *range-of-motion*

RPE: *Rating of perceived exertion*

Rpm: *Revolutions per minute*

S&C: *Strength and conditioning*

SD: *Standard deviation*

STD: *Conventional/standard seat-back*

START: *Start of rep (arms in full horizontal abduction)*

TW: *Total work*

UL, LL: *Upper limit, lower limit*

1.0 Introduction

1.1 Background Context

We theorise that an overemphasis on conventional flat bench press training could interfere with 'natural' shoulder girdle functional movement patterns. The traditional use of the bench press exercise is to develop upper-body strength, with the exercise being commonplace in most prescribed training programmes. Strength and Conditioning (S&C) coaches often use the flat bench exercise to improve, and test upper-body strength, usually with a heavy emphasis on concentric strength development.

Upper-body strength can be viewed as a necessary physical attribute in a plethora of sporting pursuits. Currently there is the assumption that training to increase upper-body strength will transfer to meet the demands of a sport that involves upper-body activities. For example, in rugby union there is an advantage to being physically dominant, to beat opponents and to gain or defend valuable territory. Intuitively, being bigger, faster, and stronger provides physical superiority. However, this thinking ignores the unpredictable and reactive requirements that are part of the evasion aspects of rugby. For example, when on 'attack' and in possession of the ball, players will try to avoid contact with defending players in order to achieve territorial advantage. This situation alone has many permutations; any contacts, including their magnitude and vector (direction of force application) are dependent on the direction and velocity of both the attacker (s) and defender (s). These can lead to situations where constrained movement patterns, as developed in a weight training environment, may be functionally problematic in the field. Inherent in these situations is the possibility that a 'weight-room strong' individual may have a compromised ability to apply

forces to overcome oncoming external forces, with injury a possible consequence. Therefore, there is a need to be able to absorb/control various forces over a range of movement patterns.

The ability to absorb and control force is often overlooked, with typically, a minor training emphasis placed on improving these abilities, compared with the greater emphasis placed on concentric force production. Ploutz-Snyder, Tesch & Dudley (1998) found that concentric-only training increased the vulnerability to eccentric exercise dysfunction and muscle injury. Strength and conditioning traditionally emphasises concentric strength, particularly in core exercises like the bench press. Consequently, eccentric strength development may not be optimised in traditional strength and conditioning programmes. Eccentric strength not only helps to increase the cross-sectional area (CSA) of muscle (Franchi, Reeves & Narici, 2017), but also appears to have a role in injury prevention (Ploutz-Snyder, Tesch & Dudley, 1998). Furthermore, the inability to absorb/control force is a primary mechanism for strain injury (Lieber, 2002). The tissue at the site of the strain may be unable to resist the force applied to the associated structure/lever often resulting in a strain injury.

It is interesting, then, to note the increased prevalence of shoulder injury in rugby union. When rugby union became professional in 1996, the incidence of shoulder injury was 1 per 1000 playing hours (Garraway & Macleod, 1995). Twenty years later that incidence is 13 per 1000 playing hours (Usman, McIntosh, Quarrie & Targett, 2015).

With professionalism there has been an increased emphasis on strength training within rugby. This emphasis is likely in response to coaches' and selectors' desires to obtain performance advantages and to be competitive. Improvements in physical attributes such as strength, power, speed, agility/change-of-direction ability, and stamina, may all be viewed as being beneficial to achieving optimal playing performance. If this is the case, and coaches

and selectors see the importance of physical attributes being measured, tracked, and compared, then strength testing is likely to be routinely employed by S&C coaches.

Methods of fitness testing usually seek a single output measure. Strength tests are often constrained, limiting some degrees of freedom to ensure easier movement standardisation and therefore improved test reliability. The output measures are, more often than not, recorded at the completion of a concentric phase and are, therefore, considered representative of force production abilities. For example, when measuring the physical attribute of upper-body strength the one-repetition-maximum test (1-RM) is used on the flat bench press, and the output measure is recorded at the completion of the concentric phase. When the user is under heavy loading, their 'natural' shoulder girdle function may be restricted and the functional pressing movement compromised due to the width (20-30cm) of the flat bench backing.

Bench press results are generally held in high regard by individuals, strength and conditioning coaches and coaches, and are often compared with the results of other players. It should come as no surprise then that players seek to improve their bench press scores, often neglecting other conditioning considerations. To players, measures, such as the 1-RM bench press, are viewed as determinants of performance and a deciding factor for team selection.

1.1.1 Statement of problem

As discussed, the flat bench press setup is a mainstay in many prescribed training programmes and is unrivalled in its use for, presumably, indicating (testing) and enhancing (training) an individual's upper-body strength. To the researcher's knowledge, the flat bench press setup has undergone little scrutiny regarding its functional utility.

1.1.2 Purpose

We argue that the traditional flat bench press setup inhibits the natural shoulder girdle function, specifically by restricting scapula mobility and is, therefore, not functionally specific to many practical upper limb movements. Before exploring alternative prescriptions or approaches to the setup and execution of the bench press exercise, it is important to establish that pressing strength can be measured reliably through a more 'functional' range of motion. This will be achieved by using a standard bench back support and a custom made, narrower bench back support.

1.1.3 Objectives

This study seeks to answer four questions:

   a) Do the torque-angle profiles of the pressing motion differ between a conventional flat-bench setup and a narrow bench setup?

   b) Are there contralateral differences in the torque-angle profiles for a pressing movement?

   c) Can torque and joint angle profiles be measured reliably throughout a unilateral pressing motion using a novel isokinetic dynamometer setup technique?

   d) Are there differences between eccentric and concentric torque-angle profiles for a unilateral pressing movement?

1.1.4 Hypotheses

It is hypothesised that:
   1. The narrow bench setup will differ in two ways: (1) There will be a greater range of motion shown overall; and (2) more work will be done in the deeper range (initial 5°

range of motion, see Section 2.3 *Figure 3*), ultimately, leading to more total work done.

2. A participant's dominant arm will yield greater torque measures than their non-dominant arm.

3. Acceptable reliability (ICC's > 0.7) will be achieved for torque-angle measurements, with angle of peak torque a likely exception due to the multi-joint nature of the pressing motion.

   a. Peak torques will be generated earlier (in the deeper range - initial 5° range of motion) with the narrow seat-back condition.

4. Eccentric torque will be greater in magnitude than concentric torque.

2.0 Review of the Literature

The review of literature chapter will explore the theoretical and conceptual framework for this thesis. The nature of the bench press exercise will be described and critiqued, with an emphasis on it's relationship to the "pressing motion". The physical attribute of upper-body strength will be discussed through it's intrinsic means, i.e. it's kinetic chain, length-tension relationship and mechanical advantage. Also, methods that aim to enhance upper-body strength will be discussed, through the investigation of concentric and eccentric training techniques that influence force production and absorption. Aspects of reliability will also be highlighted due to the studies purpose and objectives.

2.1 The Bench Press

The barbell bench press is the most commonly prescribed upper-body resistance training exercise, being used primarily to improve and test for, upper-body hypertrophy, strength and power (Kolber, Beekhuizen, Cheng & Helman, 2010). The typical flat bench press setup employs a bench with approximate dimensions of a height 40 cm from the ground, 120 cm long and 20-30 cm wide. The barbell is typically 2 m long and 5 cm in circumference. The exercise utilises the 'pressing motion' that requires a participant to lie supine on a bench and lower a weight (loaded barbell) toward their mid-chest and to then 'push' it away. The forearms are pronated when gripping the bar. As the weight is lowered the elbows flex, the glenohumeral joint (GHJ) abducts horizontally, and the scapulae retract until the barbell contacts the mid-chest. The weight is then pushed away, with the GHJ adducting horizontally, the scapulae protracting and the elbows extending.
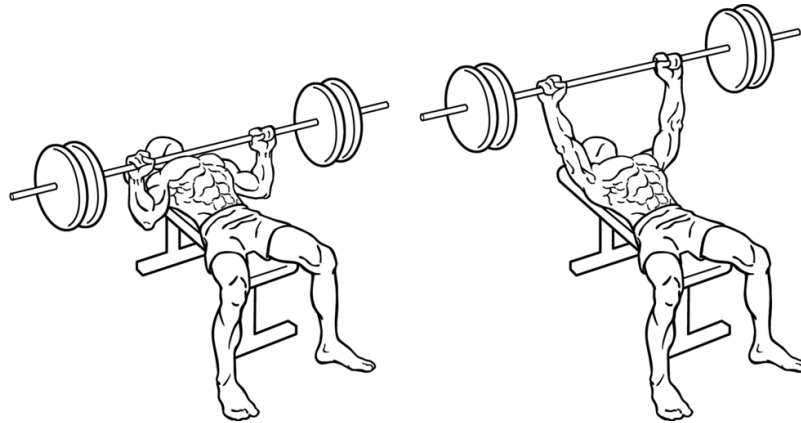
Figure 1. Traditional barbell bench press exercise (https://6packlapadat.files.wordpress.com/2011/08/bench-press.png).

The pressing motion is, effectively, a closed kinetic-chain exercise as the grip locks the wrists to the barbell throughout the movement and the wrist, elbow, glenohumeral and scapulothoracic articulations participate in the movement. Because the barbell lies in the horizontal plane (relative to the body) it encounters the mid-chest when lowered, preventing a full shoulder horizontal abduction range-of-motion (ROM). Another contributing factor to reduced shoulder horizontal abduction ROM is the width of the bench, which tends to prevent a 'normal' range of scapula retraction. The 'pinch' technique has been developed by power-lifters. This is where the lifter retracts their scapulae to their near maximum range and actively holds the scapulae in this position. It is employed by the lifter to provide a stable base on the bench and, consequently, offers optimal leverage to lift more load. However, with the scapulae likely remaining 'locked' in place throughout the whole exercise, it may, inadvertently, restrict anterior shoulder girdle ROM, which is normally facilitated by scapula protraction. When scapula movement and shoulder ROM are restricted the optimal (natural) movement sequence (kinetic chain) of a pressing motion may not be realised.

When the weight is lowered, the key muscle groups act eccentrically (absorbing force) to control the lowering of the weight and then concentrically (producing force) to push the weight back up. A standard training methodology is to test for strength gains, with a one-

repetition-maximum (1-RM) test being frequently employed for the bench press. The 1-RM test is an indicator of maximal concentric strength and, in the case of the bench press, it is often considered a proxy measure of maximal upper-body strength. This measure is therefore valued by those that believe it is an indicator of training progress and performance. However, it could be argued that the typical bench press setup and movement pattern does not involve optimised movement of the upper-body kinetic chain. Strength developed with this exercise may be effective only within a specified ROM.

2.2 The Kinetic Chain Concept

The GHJ works as a link in the kinetic chain (Kibler, McMullen & Uhl, 2012) of joint motions and muscle activations to produce optimal movement function. A kinetic chain consists of a coordinated activation of body segments. The complex function of the shoulder involves not only local anatomic and biomechanical integrity, but also biomechanical and physiologic contributions from distant body segments. Optimal function at the shoulder requires not only scapular control and coupled rotator cuff activation, but also a stable base of support and stabilising muscle contributions from the trunk and legs. This is the concept of the proximal-to-distal pathway where structures close to the site of muscle action in a movement are facilitated by activations and sequencing of further away body structures.

Function in exercise is often considered as movement replication that serves the original purpose or demands of a given activity. The proximal-to-distal pathway concept is a functional approach commonly considered in rehabilitation practices. Rehabilitation should be viewed as being towards one end of the training spectrum due to its reduced emphasis on movement intensity and complexity. The proximal-to-distal concept is applicable to all stages of training as it sets the functional foundation for the eventual progression of movement intensity and complexity. As we move along the training spectrum, the intensity of the

movement increases. Although the pressing motion could be considered a natural movement, it has been applied within the constraints of a flat-bench bench press. The pressing motion is altered in ways to accommodate the increase in intensity (higher loads applied) and the movement, subsequently, moves further from its functional applications outside of the gym environment.

The whole shoulder girdle (GHJ, acromioclavicular joint, scapular and its articulation with the thoracic region) works in unison to accomplish even the simplest of movements. In the case of the pressing motion, the associated force, whether absorbing or producing is not isolated to a single muscle or joint angle; it is subject to contributions from the whole kinetic chain.

Upper-body strength is also not limited to the pressing motion and cannot be wholly reflective of the many movements that require the strength of the upper-body. However, from a performance perspective the pressing motion applied to the flat bench press is the current proxy measure of upper-body strength and is assumed to be transferable to other movements that require such strength.

2.2.1 Chronic Effects of Resistance Training

Sport specific adaptations occur when muscle is exposed to distinctly different functions and seem to adapt to chronic functional requirements (Komi, 2003; Brughelli & Cronin, 2007). Therefore, it could be argued that persistent training using the barbell bench press may help to improve physical attributes (i.e. strength, power or endurance) within the constraints of the movements. Increased muscle bulk around the shoulder girdle is sought after, and prevalent, in professional rugby players and is usually achieved through heavy resistance training. These hypertrophic adaptations, could contribute to increased passive muscle tension and in turn influence postural deviation (Horsley, Pearson, Green, & Rolf, 2012), a factor that has

been associated with GHJ pathologies (Finley & Lee, 2003; Kebaetse, McClure & Pratt, 1999; Rubin & Kibler, 2002). Within rugby S&C there is also an emphasis on strengthening latissimus dorsi and pectoralis major, and as both muscles are strong medial rotators (Horsley, et al. 2012), the resultant increased muscle bulk increase muscle tension towards the end range of external rotation. This may be further complicated by decreased middle to inner range strength of the humeral external rotators due to a reduced focus on this action (Horsley, et al. 2012). Increased muscle bulk (and, hence, tension) within latissimus dorsi could also account for a reduced range of shoulder flexion and abduction. Furthermore, these could result in a reduced range of lateral humeral rotation and restrict GHJ elevation, resulting in postures that may not be suited for the magnitudes and directions of forces that act upon these structures in a rugby game (Horsley, et al. 2012). If the arm is unable to reach an appropriate outstretched and laterally rotated position quickly, which is common when a player attempts to evade a rugby tackle (*Figure 2*), the tissue associated with the joints involved may be tested beyond their trained means and subsequently, result in tissue damages (i.e. strains).

Figure 2. Outstretched arm positioning commonly expressed in tackles in rugby union (http://sportsscientists.com/wp-content/uploads/2016/03/rugby-tackle.jpg).

Altered postures from chronic training adaptations could lead to dysfunctional muscle structures and movement patterns. The normal response to repeated muscle stress is tightness in the agonist, along with potential weakness of the antagonist due to reciprocal inhibition, resulting in sub-optimal movement patterns (Chaitow & Crenshaw, 2006; Janda, 1978) and there may also be neglected areas outside of the trained range due to movement range limitations imposed by the barbell bench press. Strength in these ranges may be vital to optimal patterning functionally (i.e. unrestricted in a rugby tackle). Therefore, without this strength and control, individuals may be predisposed to injury (Chaitow & Crenshaw, 2006; Janda, 1978).

Lieber (2002) suggested that the inability to absorb force is a mechanism for strain injury. If musculotendinous (MTU) structures are unable to control/absorb force appropriately, forces will presumably be passed on to other structures in the kinetic chain which may result in damage of varying severity (i.e. micro-tears through to dislocations). From their findings, Ploutz-Snyder, Tesch & Dudley, (1998) suggest that an increase in the

force absorption ability (of a MTU) would likely decrease the vulnerability to strain injury at a given relative threshold.

2.3. Force Production and Force Absorption and Control

The 1-RM method of testing muscular performance is commonly advocated and employed in strength and conditioning. The test is based on lifting the heaviest load possible and has a large concentric action emphasis. When lifting higher loads, a quick eccentric phase is often employed to take advantage of the stretch shortening cycle (Komi, 2003). The rapid eccentric phase is thought to activate the myotatic stretch reflex and along with the elasticity of the MTU, uses the facilitation and elastic recoil to benefit the concentric phase of the movement. In the flat bench press exercise, however, full shoulder ROM is restricted. This could, potentially, result in a sub-optimal eccentric stretch, leading to a diminished recoil and the potential for optimal force production. Instead a compensatory method is often used to mimic or mask this deficiency. The method is called the 'chest bounce' technique, where the compressibility of the ribcage is utilised to add to the recoil, effectively, mimicking the recoil lost from maximal shoulder ROM. Eccentric ability and full concentric utilisation is restricted in range, leaving areas of the movement pattern likely unchallenged (i.e. deeper range, *Figure 3*).

Figure 3. 'Deeper' range (full horizontal abduction) of the pressing motion.

A typical repetition of the bench press requires a concentric and eccentric phase. However almost all variations of the exercise use completion of the concentric phase as the output measure. The standard requirement of the bench press 1-RM is completion of the concentric phase at 'lock-out'. Here, the agonist muscles are shortening in the concentric phase and must produce enough force to 'overcome' the load. However, when the muscle is lengthening in the eccentric phase that muscle can tolerate greater eccentric load. There is a similar order of motor recruitment in a shortening (concentric) or lengthening (eccentric) contraction when under the same load (Duchateau & Enoka, 2016), with eccentric actions having a lower rate of motor unit discharge. This better equips muscle to absorb or control inertia as described by Newton's first law where an object at rest will remain at rest or constant velocity unless acted on by an unbalanced force. When muscle shortens to overcome an external load, the force must be sufficient to overcome inertia and move the load. However, in a lengthening action muscle force can be less than the external load it 'resists'. This is due to the passive elastic properties of the muscle fibre resisting and, cross-bridge detachment and reattachment, as

fibre lengths increase (see Section 2.4). In fact, an individual's single eccentric maximal tolerated load (ECC. 1-RM) is estimated to be 30-50% greater than their maximal concentric load (CON. 1-RM; Durand, Castracane, Hollander, Tryniecki, Bamman, O'Neal & Kraemer, 2003). This suggests that, in conventional bench pressing the eccentric phase is sub-maximally loaded to allow for safe concentric phase completion. This likely leaves the eccentric phase not fully challenged and, therefore, is possibly ill-equipped to handle maximal loading. The desire to produce force, potentially, outweighs the functional need to be able to effectively absorb and control force through a full range of movement.

2.3.1 Concentric Training

Concentric dominant exercise has been shown to increase vulnerability to muscle damage when a muscle is loaded eccentrically. Ploutz-Snyder, Tesch & Dudley (1998) originally observed this, finding that "CON-only training increases the vulnerability to ECC exercise-induced dysfunction and muscle injury, probably by increasing the CON 1-RM, and thus allowing the individual to be exposed to greater ECC loading potential" (p.58). The concentric-only training allows an individual to lift a heavier maximal weight but provides sub-optimal benefit for lowering this weight (Ploutz-Snyder, et al. 1998). The concentric trained muscle, although stronger in a concentric action, is apparently ill prepared to handle the high eccentric loads that can be realised after training (Ploutz-Snyder, et al. 1998). Gleeson, et al. (2003) expanded on the underlying mechanisms and noted that sarcomeres in a stiffer (less scope for fibre lengthening) muscle are thought to be longer at any given point in the muscle contraction (Wilson, Murphy & Walshe, 1996; Wilson, Murphy & Pryor, 1994). Sarcomeres are the basic contractile units of muscle, and their lengths influence muscle force-generating capacity (Chen, Sanchez, Schnitzer, & Delp, 2016). Gleeson, et al. (2003) theorise that this may be a result of more sarcomeres contracting at lengths that correspond to

the plateau or descending limb of the length-tension curve, rendering them more susceptible to overextension and damage. Thus, during eccentric muscle actions there may be less scope in a stiff MTU to extend to accommodate the load, which exacerbates the symptoms of exercise-induced-muscle damage (EIMD; Gleeson, et al. 2003).

2.3.2 Eccentric Training

Eccentric training has been suggested as being beneficial for injury rehabilitation and increases in strength and power development for sporting performance (LaStayo, Woolf, Lewek, Snyder-Mackler, Reich & Lindstedt, 2003). Eccentric training can improve the cross-sectional area (CSA) of muscle which is a major determinant of strength (Franchi, Reeves & Narici, 2017). It is well known that a muscle can do more concentric work when preceded by an eccentric contraction (in combination with reflex facilitation) rather than an isometric contraction or no contraction (Enoka, 1988). This is due to muscle properties, such as the series elastic and parallel elastic components, being stretched and storing energy to be, subsequently, released (Enoka, 1988). The ability to use this stored elastic energy is affected by three variables; time, magnitude of stretch and velocity of stretch (Enoka, 1988). Therefore, it could be speculated that a smaller ROM (and therefore less magnitude of stretch) if consistently trained in a movement such as the bench press (e.g. where the elbow flexors/extensors are known to have an ascending-descending relationship) then the ability of the connective tissue (elastic elements) and the contractile elements to store energy throughout a complete range of motion could be decreased. This could result in less force and/or torque output outside of the trained range. Enoka, (1988) notes that, "if the magnitude of the lengthening contraction is too great, a lesser number of cross-bridges will remain attached following the stretch, and, hence, less elastic energy will be stored". Therefore, if the contractile tissue is challenged outside of the trained range, the ability to move quickly from

eccentric to concentric (a short amortisation phase) the more likely the effective control of the movement may be compromised.

Humans reflexes have evolved as mechanisms that can protect the system against unexpected muscle stretch (Enoka, 2008). Reflexes are short-latency input (afferent signal) – output (motor response or efferent output) connections that initiate rapid responses to perturbations (Enoka, 2008; Pearson & Gordon, 2000; Prochazka, Clarac, Loeb, Rothwell & Wolpaw, 2000). When the system is perturbed, as with an unexpected stretch of a muscle, reflexes can generate a rapid response that will counter-act that perturbation (Enoka, 2008). The neural circuits that enable input-output connections to compensate for such disturbances perform a negative-feedback function; that is, the motor response tends to counteract the stimulus that initially activated the sensory receptor (Enoka, 2008).

If the stretch is an adequate stimulus, a sufficient number of synaptic potentials are generated in the motor neuron to elicit an action potential that is propagated to the muscle and evoke a contraction (Enoka, 2008). The net effect of this input-output circuit is that the stretch (stimulus) will elicit a contraction (response) that minimises the stretch; this type of negative-feedback response has also been referred to as a resistance reflex (Enoka, 2008). The stretch reflex seems most capable of accommodating small disturbances in muscle length (Enoka, 2008).

When an individual attempts to learn a movement that has a resistance requirement, coactivation of the agonist and antagonist muscle of the joint/s involved is required to keep the resistance/body controlled, however, its appearance may seem untidy and inefficient. As the movement is learnt, reciprocal inhibition occurs which allows for a smooth and efficient movement to emerge. If an individual performs a well-learnt movement with the expectation to complete it successfully, but encounters an unexpected large disturbance, this would add

strain to the muscle trying to contract and that muscle may not have the ability to overcome the disturbance.

The Hoffmann reflex (H-reflex) provides some insight into reflex responses. The reflex response can be modified with chronic training (Mynark & Koceja, 1997; Nielsen, Crone, & Hultborn, 1993). For example, Sale, MacDougall, Upton, & McComas (1983) found that the H-reflex, elicited during a maximal voluntary contraction increased after a strength-training program. This effect was interpreted as reflex potentiation due to a training-induced increase in motor neuron excitability. If the H reflex is 'dialled up' in this way after training, could it exacerbate its magnitude of response to a large disturbance, leading to the innervated tissue being put under added strain?

2.4 Length-Tension Relationship

The length-tension relationship is a theoretical model used to help describe how as the length of muscle changes, tension output increases or decreases depending upon the purported muscle fibre length. This theory was originally hypothesised using in *vitro* maximal muscle activation. From this it was suggested that sarcomere overlap is most optimal when the actin-myosin heads are close enough to 'hook' and pull closer together, and it is here that the most tension can be generated (McArdle, Katch, & Katch, 2010). When the sarcomeres are too close, the amount of actin and myosin overlap means that less tension can be generated (McArdle, et al. 2010). Similarly, when the sarcomeres are too far apart the myosin heads are unable to 'hook up' with actin myofilaments and cannot generate as much tension. (McArdle, et al. 2010). Thus, 'optimal' force generating capacity is considered to be dependent on 'optimal' sarcomere length (i.e., maximal overlap), when in *vitro*.

Despite their importance, in *vivo,* sarcomere lengths remain unknown for many human muscles (Chen, et al. 2016). In *vivo* studies observe less sarcomere length change and

a wider range of lengths where force-generating capacity is not compromised (Chen, et al. 2016; Gollapudi, & Lin, 2009).

Muscle length and tension are both difficult to measure in *vivo*, however, practically, joint angle (position) and torque (force) represent these parameters indirectly (*Figure 4*). Sarcomere overlap can be influenced by moment arm length, which can be represented indirectly, by joint angle. Muscle tension has an active and passive component. Active tension occurs when the muscle attempts to contract concentrically to generate force and is greatest when there is optimal sarcomere overlap (*Figure 4*). Passive tension reflects the elastic properties of the MTU; as their length increases they are stretched, which increases tension as the MTU resists lengthening eccentrically (*Figure 4*). Torque output similarly represents active tension (*Figure 4*) as they both reflect a bell-shaped curve with an optimal point where joint angle and fibre length can produce maximal torque and tension respectively.
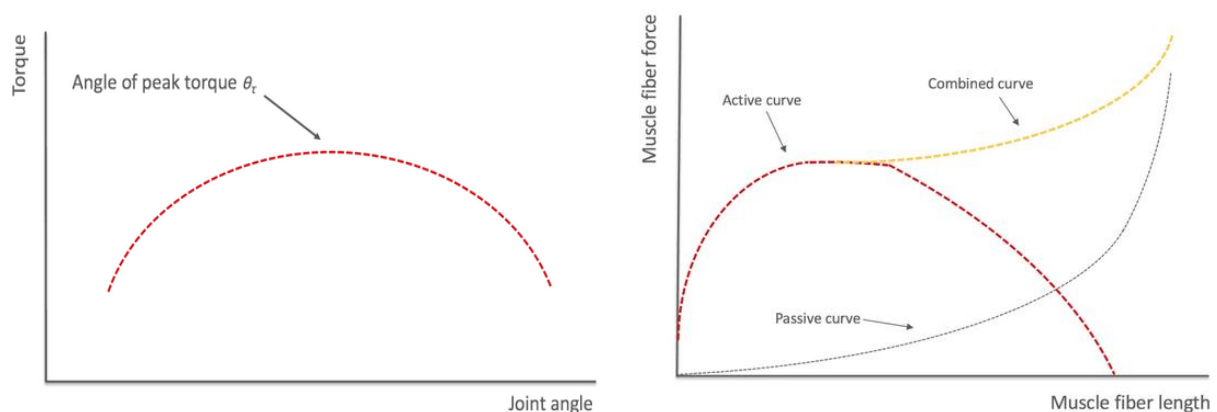
Figure 4. Indirect theoretical relationship between torque-joint angle and force-length with active and passive contributions (https://www.strengthandconditioningresearch.com/biomechanics/length-tension-relationship/).

As joint angle and muscle fibre length increase, torque and active muscle fibre force reach an optimal point/range and then decrease as joint angle and muscle fibre length

continue to increase. This association may underpin where it can be expected that peak torque occurs during a pressing motion. As muscle fibre length increases, muscle fibre force increases exponentially with passive tension. Passive tension increases in the eccentric (lowering) phase of a lift.

To the present researcher's knowledge there is no research describing the in *vivo* length-tension relationship of the chest pressing motion. Most literature explores the length-tension relationship through isometric contractions or in *vitro*, and has focused largely on the hamstring muscle group. Shoulder movements are complex due to the number of joints and articulations, the complexity of the musculature and the number of movements that can occur.

In the findings from Kilgallon, Donnelly & Shafat, (2007), eccentric hamstring training resulted in a shift of the length-tension curves to the right while concentric training saw a shift to the left, which indicates greater torque at longer muscle lengths, or more knee flexion. These results are speculated as being due to a change in the number of sarcomeres in series which may relate to decreased active stiffness at short muscle lengths and increased passive stiffness at longer muscle lengths (Kilgallon, Donnelly & Shafat, 2007). As Brughelli & Cronin (2007) state, shifting the length tension curve to the right may help reduce the risk of injury in some muscles (e.g. hamstrings) following eccentric loading. It is surmised that this is due to the optimal length being shifted to a longer length so that during performance tension can be withstood at longer muscle lengths (descending portion of the length-tension curve; Brughelli & Cronin, 2007).

2.5 Mechanical Advantage

Mechanical advantage can help with understanding the functional significance of the theoretical length (joint angle) – tension (torque) relationship. As the length of muscle

changes tension (torque/force) output, purportedly, increases or decreases, depending on the amount of sarcomere overlap. However, given the mechanical factors discussed in this section, muscle length is probably less of a factor with-in the pressing motion.

The magnitude of force that can be absorbed or produced throughout the movement range varies according to the body's muscular and mechanical advantage. Mechanical advantage is the ratio of the effort force produced by a muscle to the external force applied to the body structure by muscle actions. Mechanical advantage (*Figure 5)* is a factor of the 'moment arm', the muscle length and the angle of pull. A moment arm is the distance between a joint's axis of rotation and the line of force application. The shorter moment arm is the perpendicular distance from the line of effort force (muscle contraction) to the axis of rotation. The longer moment arm is the perpendicular distance from the line of external force (resistance) to the axis of rotation.
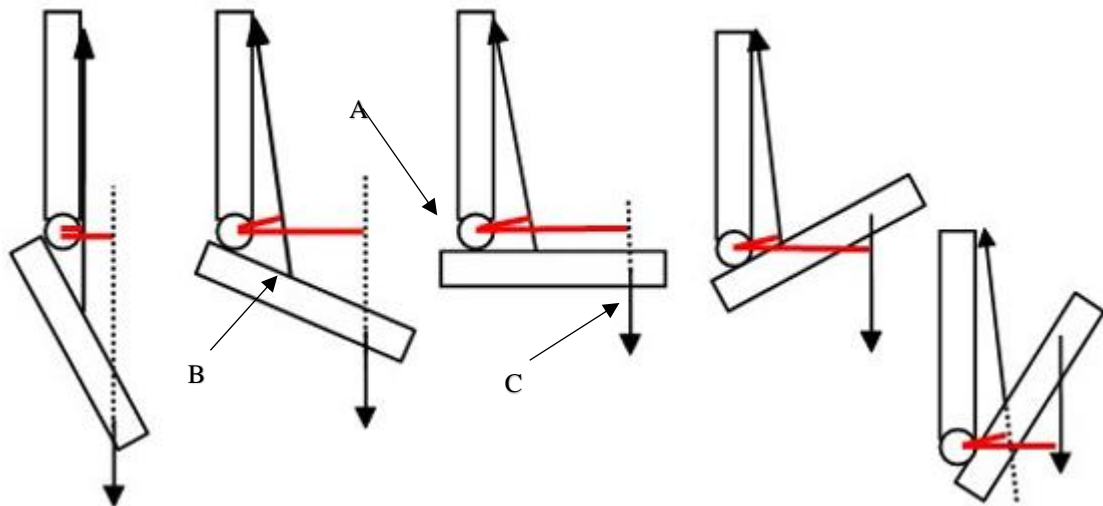
Figure 5. The effort moment arm is the distance between the joint axis (A) and site of muscle attachment (B), i.e., the short red line, while the resistance moment arm is the distance between the joint axis and line of external force (C), i.e., the longer red line (http://exerciseeducation.com/moment-arm/).

Four joint complexes participate in the pressing motion. The scapulothoracic is the most proximal articulation of the shoulder girdle. The scapula glides medio-laterally along the ribs of the thoracic region, which results in the GHJ moving anteriorly with protraction or posteriorly with retraction of the scapulae. The GHJ is the next most proximal joint/articulation with the humerus as its lever arm and force output coming, predominantly, from the pectoralis major with some assistance from the anterior deltoid (Stastny, Gołaś, Blazek, Maszczyk, Wilk, Pietraszewski, & Zając, 2017). The elbow joint is distal to the GHJ and its lever arm is the forearm (ulna and radius) with output force coming from the triceps brachii. The most distal joint is the wrist which effectively provides a stable connection to the barbell and moves in response to the pressing movement. Input force from the barbell is in line with the forearm throughout the movement. The least mechanical advantage is expected when the barbell is closest to the chest in the pressing motion. At this point the moment arm is at its shortest, as the barbell is pushed away, the moment arm lengthens, less mechanical load is applied to the GHJ and, consequently, the barbell load can be overcome.

2.6 Reliability

Reliability is the degree to which the result of a measurement, calculation, or specification can be depended upon to be repeatable (Streiner & Norman 2003). Test-retest reliability assesses the degree to which test scores are consistent from one test administration to the next. Measurements are gathered from the single rater (the researcher) who uses the same methods and testing conditions (Saal, Downey & Lahey, 1980). Intra-rater reliability is the degree of agreement among repeated administrations of a test performed by a single rater (Saal, Downey & Lahey, 1980). Inter-rater reliability is the degree of agreement among raters (Saal, Downey & Lahey, 1980).

The ICC is the most commonly used method of measuring relative reliability (Mullaney, McHugh, Johnson & Tyler, 2010). The ICC represents the relationship between the within-subjects' variability and the between-subjects' variability (Mullaney, et al. 2010). The within-subjects' variability represents biological and technical measurement error, while the between-subjects' variability represents additionally the heterogeneity of the sample (Mullaney, et al. 2010). Intraclass correlations (ICC's) provide an estimate for the relative reliability for consistency of measurement when the population under study is heterogeneous (Stratford & Goldsmith 1997). The ICC reflects a test's ability to differentiate between participants and, hence, the position of the individual relative to others in the group (Stratford & Goldsmith 1997). However, the ICC does not provide information about the accuracy of scores for an individual (Stratford & Goldsmith 1997).

2.7 Summary

Hypothetically, certain training methods may alter the optimal length-tension relationship and eccentric-concentric strength ratio, in turn, exposing muscle and joints to potential strain injury when loaded, particularly through the 'deeper ranges' (*Figure 3*) of motion that may not be loaded in training. In the case of the present study, the width of the flat bench and the bar contacting the chest can obstruct and restrict the glenohumeral and scapulae movements, movements that are argued to be a key part of the coordinated pressing movement sequence. When the movement of the scapulae are inhibited this action does not contribute to the full ROM or force production/absorption, and makes the GHJ, effectively, the most proximal part of the upper limb kinetic chain. The normal physiological ROM is reduced if scapula protraction or retraction is inhibited and this may reduce maximal eccentric ability and overall concentric ability. This all, potentially, reduces optimal functional movement of the

shoulder girdle. It could also be argued that injuries to the shoulder girdle in contact and falling situations often happen due to the inability of surrounding tissues to appropriately absorb/control the external forces encountered. Therefore, continual practice of sub-optimal movement patterning and overemphasis of concentric (force production) strength in bench pressing may increase susceptibility to shoulder girdle injury.

This dissertation proposes that the current flat-bench setup using the chest pressing movement (bench press exercise) may limit an individual's capacity to reach, or to challenge their potential maximal ROM through resistance exercise. Due to these movement limitations and a reductionist view of how upper-body strength should be assessed (i.e. 1-RM testing), pressing mechanics may be altered and ecologically invalid.

Pressing mechanics can be altered through various mechanisms. If a movement is chronically trained, the physical structures associated may adapt in ways that efficiently meet the requirements of the movement. However, such structural changes might lead to altered postures and dysfunctional muscle structure for other movements that the body is required to perform, potentially, predisposing structures to injury. For example, training solely concentrically would increase concentric ability, but also, inadvertently, increase vulnerability to eccentric exercise-induced dysfunction and muscle injury (Ploutz-Snyder, et al. 1998).

Upper-body strength is influenced by other factors (e.g. the need to control and absorb force, maintain/hold constant sub-maximal and maximal tension) and can be expressed in a variety of means. By observing the movement requirements in the game of rugby union the multitude of ways upper-body strength is required becomes obvious, yet upper-body strength is conceptually emphasised in strength and conditioning through supine lying barbell-loaded bench press in the vertical plane, with the key result being the load completed concentrically.

This begs the question, are there other approaches to considering upper-body strength that better reflect the demands of a given sport? Additionally, in the context of this study, are there alternatives that may help to improve performance and also reduce the shoulder injury incidence in rugby union? A transition to more functionally specific forms of training and testing needs to be conceptualised in order to explore such questions. Therefore, this project seeks to take a first step in exploring whether pressing strength can be measured through a functional and physiological range of motion with reliability.

3.0 Methods

3.1 Overview

To evaluate chest pressing strength and changes in strength, a valid and reliable method of measuring concentric and eccentric torques is required. This project was a reliability study to determine whether a unilateral chest pressing movement could be measured reliably during eccentric (ECC) and concentric (CON) actions.

Institutional ethical approval was obtained for this project from the University of Otago Human Ethics Committee (H17/039) and the Ngāi Tahu Research Consultation Committee

3.2 Participants

The objective was to recruit participants representing a range of resistance training experiences. This is in keeping with other strength testing reliability studies and allows for a reasonably heterogenic sample within the limitations imposed by a Masters' research project.

Participants (n=20) were recruited from a university student population via study advertisement in classes at the School of Physical Education and direct contact by the researcher. A range of currently active resistance-trained and untrained participants (19 male, 1 female) were recruited, aged between 19 and 29 years. Potential participants were excluded if they had previous shoulder girdle/associated tissue or bone surgeries or any major injury that still required treatment/rehabilitation or that could be aggravated by strenuous exercise. Current neck, spine and/or any neural complications were also grounds for exclusion. Participants completed screening to ensure that they met the entry criteria. They were

provided with information on the testing and protocols, and were required to provide informed consent before commencing the study.

3.3 Procedures

3.3.1 Movement Task

A unilateral 'pressing' movement was performed using a modified lever arm and attachment (*Figure 6*) on a Biodex System 2 Isokinetic Dynamometer (Biodex Medical Inc., Shirley, NY). Participants were seated in the Biodex chair and secured with a waist strap to attempt to limit trunk movements (rotation, flexion, extension, lateral flexion and extension) and, thus, isolate the pressing movement as much as possible. To assist with eliminating extraneous trunk movements, participants performed a simultaneous pressing movement with the contralateral limb, pressing against a cable bungee.
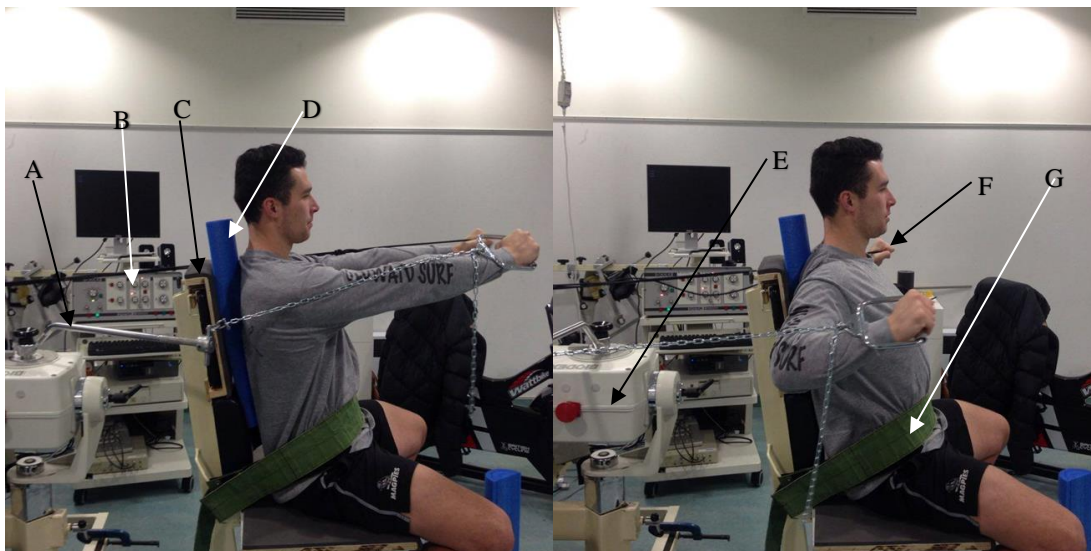
Figure 6. Participant setup. Left picture shows full protraction and right shows full retraction. A = Lever arm, B = Biodex control panel, C = STD backing of Biodex chair, D = MOD backing, E = Biodex power head, F = Elastic bungee resistance, G = Waist strap.

Participants were instructed to, "keep their fists in alignment as if both hands were holding a bar and to keep both arms moving in unison as if performing a seated chest press". While the resistance provided to this movement was minimal, participants reported, during pilot testing, that the bilateral movement felt 'more natural' and less extraneous trunk movements were observed. To obtain measures for both eccentric and concentric torque the passive mode of the Biodex was used. This was due to the difficulties triggering eccentric loading in the end range of shoulder horizontal abduction. The passive mode allowed participants to, respectively, resist and assist continuous eccentric and concentric passive movement.

Angular velocity was set at 90°/s to replicate the typical cadence of a bench press repetition (González-Badillo & Sánchez-Medina, 2010)

Two different seat-backs were used in an attempt to influence scapulae range of motion. These were a conventional (STD) seat-back (30cm breadth) and a narrow (MOD) solid foam back rest (*Figure 7*; 15cm breadth with two hollowed groves 0.5cm from the backing's midline).

Figure 7. Narrow seat-backing strapped to the conventional backing

Participants attended a familiarisation session where individual seat setting and lever arm adjustments were made and recorded for subsequent testing sessions. Participants were instructed on how to perform pressing movements with both arms at a speed of 90°/s and became familiar with applying force throughout the movement using both the MOD and STD setups.

Participants performed three testing sessions separated by two to seven days. Each session, including warm up and warm down, took no more than 45 min.

3.3.2 Participant Preparation

Prior to each testing session, participants completed a standardised warm up consisting of 10 minutes of arm ergometry at an intensity producing a rating of perceived exertion of 12 on the linear Borg Scale (6-20; Borg, 1982). Dynamic pectoralis major and minor, triceps brachii and latissimus dorsi stretches were also instructed. Warm down consisted of the participant performing slow-paced (60 rpm) revolutions on the arm ergometer until 6-8RPE was

reported. Static pectoralis major and minor, triceps brachii and latissimus dorsi stretches were also instructed.

Participants were seated in the Biodex chair in a neutral position and a waist strap was used to secure participants in the chair. They were instructed to limit undesirable movements (mainly trunk movements). The Biodex power head was tilted 90° and the power head height was adjusted to allow for the lever arm and the pressing movement to be in the horizontal plane. In this position the chain and pressing trajectory were parallel to the floor. The chain length was adjusted to ensure that the lever arm would not come into contact with the chair and/or the participant's body. The participant's scapulae were observed and palpated during setup and the MOD foam height was adjusted vertically so that the scapulae could move freely during the pressing movement. That height was marked on the Biodex chair back, recorded, and replicated for subsequent testing sessions.

3.3.3 Biodex Settings

Pressing movement range was set so that participants could choose their maximal comfortable range of horizontal abduction (START = "pull your arm as far back as possible") They then moved through a full pressing movement until they reached their maximal pressing range of motion (END = "extend your arm out fully in front of you"). The Biodex was set to 'Passive' mode and velocity was increased in 15°/s increments from 30°/s until 90°/s was attained. Participants were encouraged to perform five repetitions under constant maximal effort (attempting to push and keep tension against the handle at all times). Participants were instructed to, "push as hard as possible against the lever arm until all the reps are completed – keep pushing even when the lever arm changes direction quickly". The movement from START to END was concentric followed immediately by resisting eccentrically as the movement reversed and went from END to START. Participants completed three sets of five

repetitions, with a five min rest between sets. The setup was then altered to enable

participants to complete three sets of five repetitions with each arm and in both the STD and

MOD seat-back conditions. The pressing range (ROM) was reset before the first set with

each change of seat-back or limb in all sessions. The tested limb and seat-back conditions

were assigned randomly but in a balanced order. The left or right limbs were tested with each

seat-back condition before the setup was altered to complete the contralateral limb. This was

to avoid variable rest times within and between participants caused by the length of time to

affect the Biodex adjustments.

Table 1. Inter-session time-line

Familiarisation (30 min)	2-7 days	Test session 1 (45 min)	2-7 days	Test session 2 (45 min)	2-7 days	Test session 3 (45 min)

Table 2. Familiarisation session

Demographic information, participant setup, recording of individual adjustments (10 min)	Warm up (5 min)	Familiarisation with the pressing motion (10 min)	Warm down (5 min)

Table 3. Example testing sessions (participant assigned randomised and balanced order)

Session 1	Session 2	Session 3
Warm up (10 min)	Warm up (10 min)	Warm up (10 min)
Set 1. *Left Arm MOD*	Set 1. *Left Arm STD*	Set 1. *Right Arm STD*

Rest (5 min)	Rest (5 min)	Rest (5 min)
Set 2. *Left Arm STD*	Set 2. *Left Arm MOD*	Set 2. *Right Arm MOD*
Rest (5 min)	Rest (5 min)	Rest (5 min)
Set 3. *Right Arm STD*	Set 3. *Right Arm MOD*	Set 3. *Left Arm STD*
Rest (5 min)	Rest (5 min)	Rest (5 min)
Set 4. *Right Arm MOD*	Set 4. *Right Arm STD*	Set 4. *Left Arm MOD*
Warm down (10 min)	Warm down (10 min)	Warm down (10 min)

3.4 Data Capture and Processing

Torque (Nm), angle (°), and angular velocity (°/s) were collected at a sample rate of 1 kHz from all sets using LabChart (ADInstruments, Bella Vista, NSW). These data were subsequently, exported into spreadsheets for off-line analysis. The START and END of each rep were identified to specify the concentric (CON) and eccentric (ECC) parts of each set. This was done by multiplying angular velocity by torque. A value of 30 Nm/s was used to identify the sample corresponding with the beginning and end of each ECC and CON repetition. The first and last reps of the five reps were discarded to eliminate the reps where warm up/priming (rep 1) and fatigue (rep 5) produced inferior torque outputs. Thus, reps 2, 3, and 4 remained for further analysis. From these data, peak torque (PT), angle of peak torque (°PT), and ROM (using angle°) were identified for each repetition (*Figure 8*). Total work done (TW) was calculated as the product of the area under the curve and the range of motion for that set. As the transition from eccentric to concentric actions was of particular interest, total work done over the initial 5° of the range of each movement was also calculated (IW). This range was chosen because it likely represents the range untrained in flat-bench barbell

bench pressing. For PT, TW and IW measures, the participant's highest (PEAK) of three sets, and the mean of three sets (MEAN) obtained on each testing session were found. Within sessions, the °PT chosen for subsequent analysis was derived from the set with the highest PT, and the ROM was the maximum ROM across sets. PEAK measures were used because this reflects common practice in isokinetic testing and MEAN measures because they may be used in a more clinical rehabilitation setting.

The torque ratios between ECC and CON were also calculated. Peak torques from both actions were compared, as well as the ECC torque at CON PEAK and the CON torque at ECC PEAK. The ECC PEAK was divided by CON PEAK to give the ECC : CON ratio. Also, muscle action PEAKS (eccentric and concentric) were divided by their opposing action at the corresponding angle of peak torque.
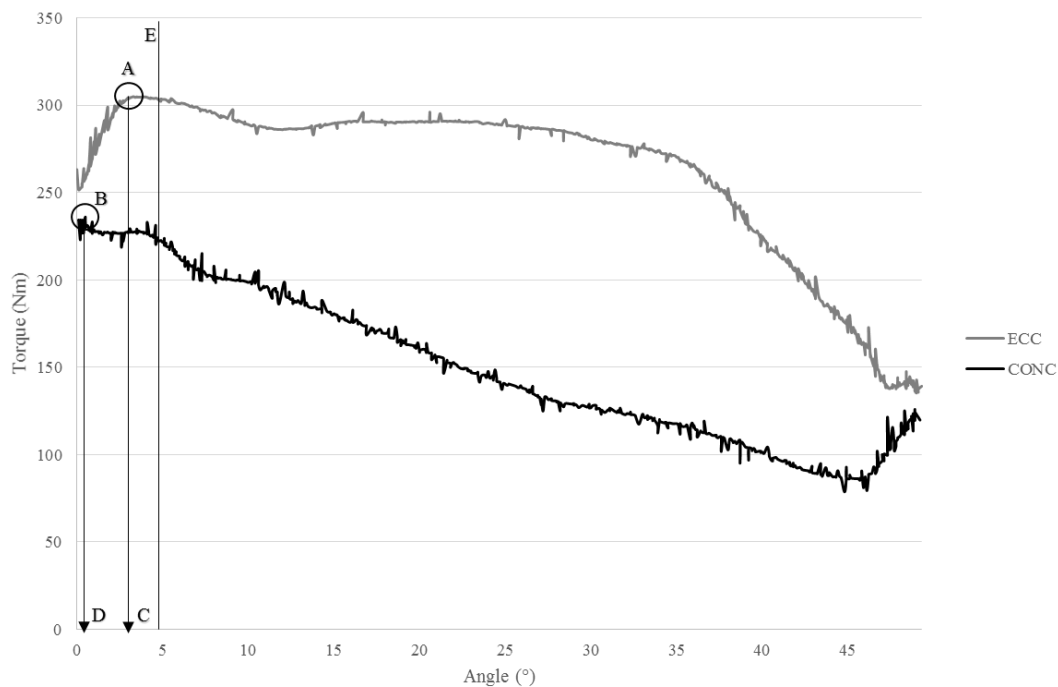
Figure 8. Example of eccentric and concentric torque-angle curves from a single set. A = eccentric peak torque, B = concentric peak torque, C = eccentric angle of peak torque, D = concentric angle of peak torque, E = 5° range indicating area of interest for initial work done.

Table 4. Summary of Key Variables

Variable name	Abbreviation	Unit	Description
Range-of-motion	ROM	°	The total range the lever-arm travelled from START to END
Peak torque	PT	Nm	The maximum measure of torque during a rep
Angle of peak torque	°PT	°	The angle of the lever arm when peak torque was recorded
Total work done	TW	100kJ	The product of the area under the curve and the range of motion for that set.
Total work of initial 5° ROM	IW	kJ	The product of the area under the curve and the range of motion for that set for the first 5° of ROM

3.5 Statistical Analysis

For all measured variables the mean, standard deviation and 95% confidence intervals were calculated using Excel. Analysis of variance was conducted using a three-way ANOVA using Graphpad Prism 7 (GraphPad Software, 7825 Fay Avenue, Suite 230 La Jolla, CA 92037 USA) to assess the effect of the seat-back condition (MOD v STD), limb (left v right) and session on the measured variables.

Reliability was calculated using Intraclass correlations (ICCs). ICC estimates and their 95% confident intervals were calculated using a custom Excel spreadsheet for calculating consecutive pairwise analysis of trials for reliability (Hopkins, 2016).

To assess reliability, the recommendations of Fleiss (1986) were adopted as follows: 0.9 or greater indicated excellent reliability; 0.9 - 0.8 indicated good reliability; 0.8 - 0.7 was acceptable reliability; 0.7 - 0.6 indicated questionable reliability; 0.6 - 0.5 poor reliability and < 0.5 unacceptable reliability (Fleiss, 1986). Based on the recommendations of Fleiss (1986), 0.7 and above was selected as a reliable measure to remain consistent with previous test-retest methodologies.

4.0 Results

4.1 Participants

Twenty volunteers completed the screening, familiarisation session, and three testing sessions. Testing sessions were separated by two to seven days. No participants reported muscle soreness from any testing session. Three participants reported performing upper-body resistance training the day before or on the day of testing, and reported feelings of muscle soreness or fatigue. However, there were no obvious indications that this prior exercise influenced the participants' measures. No soreness was reported because of the testing sessions by any participant.

Table 5. Participant characteristics

Participant	Age	Height	Mass	Resistance Training	Contact Sport	Throwing Sport	Arm Dominance (self-reported)
n=20				n=16	n=13	n=5	
Mean ± SD	23 ± 3 yr	1.78 ± 0.08 m	82.86 ± 12.85 kg	4 ± 3 yr	5 ± 6 yr	3 ± 4 yr	18 Right, 1 Left, 1 Ambidextrous

4.1.1 Group Isokinetic Torque Data

For all measures, the maximum measure (PEAK) and mean of three sets of session (MEAN) for each participant were grouped for means, standard deviations (SD), and 95% confidences intervals (UL, LL) for each of the three sessions. Refer to ANOVA's (section 4.2) for outcomes of limb, seat-back and session comparison.

Table 6. Mean data (SD + 95% CIs) – Peak torque, angle peak, total work for eccentric and concentric, narrow and conventional seat-back, and left and right arms

	Group means ± SD (95%CI)		
	Session 1	**Session 2**	**Session 3**
Range of motion (°)	65.2 ± 9.5	62.7 ± 9.0	63.1 ± 8.2
	(61.0, 69.4)	(58.8, 66.7)	(59.5, 66.7)
Eccentric			
Peak torque (PEAK set, Nm)	236.1 ± 54.7	246.9 ± 56.1	264.5 ± 55.4
	(212.1, 260.1)	(222.4, 271.5)	(240.2, 288.8)
Angle of peak torque (°)	16.6 ± 18.8	17.5 ± 19.1	19.8 ± 20.0
	(8.4, 24.8)	(9.1, 25.8)	(11.0, 28.5)
Total work (PEAK of 3 sets, 100kJ)	83.2 ± 26.4	85.1 ± 21.8	91.9 ± 27.0
	(71.7, 94.8)	(75.5, 94.6)	(80.0, 103.7)
Total work of initial 5° ROM (PEAK of 3 sets, kJ)	82.0 ± 24.4	85.4 ± 22.7	95.0 ± 23.4
	(71.3, 92.7)	(75.5, 95.4)	(84.8, 105.3)
Concentric			
Peak torque (PEAK set, Nm)	207.2 ± 52.1	219.0 ± 46.0	228.1 ± 50.0
	(184.4, 230.0)	(198.9, 239.2)	(206.2, 250.0)
Angle of peak torque (°)	70.5 ± 19.5	72.7 ± 22.5	77.7 ± 21.4
	(62.0, 79.1)	(62.8, 82.4)	(67.7, 86.4)
Total work (PEAK of 3 sets, 100kJ)	74.1 ± 20.2	77.1 ± 24.2	81.6 ± 22.0
	(65.3, 83.0)	(66.5, 87.7)	(72.0, 91.3)
Total work of initial 5° ROM (PEAK of 3 sets, kJ)	138.7 ± 34.6	155.2 ± 36.5	162.0 ± 37.6
	(123.6, 153.9)	(139.2, 171.1)	(145.5, 178.5)
Ratios			
Peak Torque ECC : CON (Nm)	1.18 ± 0.29	1.15 ± 0.24	1.17 ± 0.14
	(1.06, 1.31)	(1.04, 1.25)	(1.11, 1.23)
CON at ECC PT ECC : CON (Nm)	1.91 ± 1.09	1.74 ± 1.09	1.61 ± 0.52
	(1.43, 2.38)	(1.27, 2.22)	(1.38, 1.84)
ECC at CON PT	1.65 ± 0.78	1.38 ± 0.41	1.19 ± 0.27

CON : ECC (Nm)	(1.31, 1.99)	(1.20, 1.56)	(1.07, 1.31)

4.2 Analysis of Variance

A three-way ANOVA was conducted to examine the effect of the seat-back condition, the limb used, and reps (ECC and CON; *Table 6*). No significant differences were evident between the two seat-back conditions ($p > 0.099$; MOD v STD) for any measure. There were also no significant differences between LEFT and RIGHT limbs ($p > 0.078$) for any measures. There were no interactions between seat-back conditions, the limb used, or reps. All data were then pooled across for subsequent reliability assessment of eccentric and concentric actions.

Table 7. Obtained values from ANOVA's of measures between arms, and conditions

	F (degrees of freedom numerator, denominator) = F value, p value	
	Left v Right	**Seat-back condition**
Range of motion (°)	F(1, 38) = 1.254, 0.270	F(1, 38) = 0.282, 0.599
Eccentric		
Peak torque (Nm)	F(1, 684) = 0.162, 0.688	F(1, 684) = 1.455, 0.228
Angle of peak torque (°)	F(1, 684) = 0.370, 0.543	F(1, 684) = 0.712, 0.399
Total work (100kJ)	F(1, 684) = 3.108, 0.078	F(1, 684) = 0.189, 0.664
Concentric		
Peak torque (Nm)	F(1, 684) = 0.179, 0.673	F(1, 684) = 2.737, 0.099
Angle of peak torque (°)	F(1, 684) = 0.006, 0.939	F(1, 684) = 5.669, 0.452
Total work (100kJ)	F(1, 684) = 1.248, 0.264	F(1, 684) = 0.001, 0.976

4.3 Reliability Assessments

For the next stage of analysis, measures were compared across sessions using ICC's. Correlations were calculated using: a). The highest (PEAK) torque or total work from the three sets, and b). The mean torque or work from three sets (MEAN) obtained on each testing session. For ROM, the maximum ROM during that session was used for analysis. To assess the magnitude of change across sessions, the percentage mean change between sessions was calculated. Post-hoc analysis comparing session one and three was also conducted and meaningful results were reported.

4.3.1 Range of Motion (ROM)

While the reliability for ROM was 'acceptable' (Table 7), ROM appeared to decrease from the first session to the second and third session by 3.2% and 2.6%, respectively.

Table 8. Intraclass correlation coefficients comparing sessions and percentage mean change for range of motion

| | Intraclass correlation coefficients of Testing Session | | |
| | % Mean change ± SD between session (95% CI) | | |
	1 v 2	2 v 3	Mean ICC
PEAK	0.74 (0.64, 0.81)	0.77 (0.68, 0.84)	0.75 (0.67, 0.81)
	-3.2 ± 10.3% (-7.7, 1.3)	1.1 ± 8.7% (-2.7, 5.0)	

4.3.2 Peak Torque

Reliability was 'acceptable' (Table 8) for peak torque measures between session two and three. This suggests that a second testing session is needed to ensure reliability when measuring eccentric torque. The reliability was 'good' for other measures concentrically across all sessions indicating that one testing session should be sufficient to obtain reliable measurements. The reliability for eccentric measures between session one and three was 'poor' (< 0.57) and increased by ~15%.

Table 9. Intraclass correlation coefficients comparing sessions and percentage mean changes for peak torque

		1 v 2	2 v 3	Mean ICC
		Intraclass correlation coefficients of Testing Session		
		% Mean change ± SD between session (95% CI)		
ECC	MEAN	0.62 (0.49, 0.72)	0.75 (0.66, 0.82)	0.69 (0.59, 0.76)
		2.4 ± 16.5% (-4.8, 9.6)	10.6 ± 18.0% (2.7, 18.5)	
	PEAK	0.63 (0.51, 0.73)	0.73 (0.63, 0.80)	0.68 (0.58, 0.76)
		6.2 ± 19.7% (-2.4, 14.9)	8.3 ± 14.5% (2.0, 14.7)	
CONC	MEAN	0.81 (0.72, 0.87)	0.85 (0.78, 0.90)	0.83 (0.76, 0.88)
		6.9 ± 12.5% (1.5, 12.4)	5.3 ± 9.7% (1.0, 9.5)	
	PEAK	0.83 (0.76, 0.88)	0.86 (0.81, 0.90)	0.85 (0.79, 0.89)
		7.6 ± 13.5% (1.7, 13.6)	4.4 ± 9.3% (0.3, 8.5)	

4.3.3 Total Work Done

Reliability was 'acceptable' (Table 9) for both eccentric measures of total work between session two and three indicating, at least, a second session was needed for acceptable reliability. Given that there was still improvement in torque from the second to the third

session, it may be that a third session will provide even better reliability. The reliability was 'good' for both concentric measures across all sessions indicating that one testing session should be sufficient to obtain reliable measurements. The reliability for eccentric measures between session one and three was 'poor' (< 0.51) and increased by ~17%.

Table 10. Intraclass correlation coefficients comparing sessions and percentage mean change for total work

| | | Intraclass correlation coefficients of Testing Session | | |
| | | % Mean change ± SD between session (95% CI) | | |
		1 v 2	2 v 3	Mean ICC
ECC	MEAN	0.58 (0.44, 0.69)	0.64 (0.51, 0.73)	0.62 (0.52, 0.71)
		3.2 ± 27.7% (-9.0, 15.3)	14.7 ± 25.2% (2.7, 18.5)	
	PEAK	0.60 (0.46, 0.70)	0.60 (0.46, 0.70)	0.68 (0.58, 0.76)
		6.7 ± 26.7% (-5.0, 18.4)	8.8 ± 22.8% (-1.1, 18.8)	
CONC	MEAN	0.73 (0.61, 0.82)	0.84 (0.77, 0.90)	0.79 (0.71, 0.86)
		4.5 ± 16.9% (-2.9, 11.9)	7.4 ± 12.3% (2.0, 12.8)	
	PEAK	0.78 (0.70, 0.84)	0.87 (0.82, 0.91)	0.78 (0.77, 0.88)
		5.4 ± 16.9% (-2.0, 12.8)	7.2 ± 12.5% (1.7, 12.7)	

4.3.4 Work Done of Initial ROM

The reliability for the work performed in the first 5° of ROM was 'acceptable' for eccentric measures between session two and session three. This indicates that a second and, possibly, a third session is needed to ensure reliability, despite there still being an improvement from the second to the third session. The reliability was 'acceptable' for both concentric measures across all sessions, indicating that one testing session should be sufficient to obtain reliable measurements. The reliability for eccentric measures between session one and three was 'poor' (< 0.51) and increased by ~20%.

| | | Intraclass correlation coefficients of Testing Session | | |
| | | % Mean change ± SD between session (95% CI) | | |
		1 v 2	2 v 3	Mean ICC
ECC	MEAN	0.61 (0.48, 0.71)	0.79 (0.71, 0.85)	0.71 (0.62, 0.78)
		6.5 ± 21.5% (-2.9, 15.9)	12.1 ± 21.4% (2.7, 21.5)	
	PEAK	0.65 (0.53, 0.75)	0.76 (0.67, 0.83)	0.71 (0.63, 0.79)
		6.8 ± 20.6% (-2.3, 15.8)	12.3 ± 16.9% (4.9, 19.7)	
CONC	MEAN	0.60 (0.46, 0.70)	0.84 (0.78, 0.89)	0.72 (0.64, 0.79)
		11.8 ± 24.6% (1.1, 22.6)	6.7 ± 11.4% (1.7, 11.7)	
	PEAK	0.67 (0.55, 0.76)	0.84 (0.77, 0.88)	0.75 (0.67, 0.82)
		13.5 ± 24.3% (2.6, 24.0)	5.8 ± 12.5% (0.3, 11.3)	

4.3.5 Angle of Peak Torque

The PEAK measures for both eccentric and concentric actions (Table 11) showed 'questionable' to 'poor' reliability (all <0.53) for both contraction modes and between all testing sessions.

Table 12. Intraclass correlation coefficients comparing sessions of angle of peak torque

| | | Intraclass correlation coefficients of Testing Session | | |
		1v2	2v3	Mean ICC
PEAK	ECC	0.32 (0.15, 0.48)	0.51 (0.36, 0.63)	0.44 (0.32, 0.56)
	CONC	0.48 (0.32, 0.61)	0.53 (0.38, 0.65)	0.48 (0.36, 0.60)

5.0 Discussion

Participants drawn from a university student population participated in this project to assess the reliability of a unilateral pressing motion using two seat-back configurations designed to influence scapula mobility (STD, MOD). As there were no significant differences between the seat-back conditions or the left and right limbs, data were pooled to explore reliability. There was speculation of a learning effect post-hoc after initial ICC results, therefore session one and three were also compared to assess the magnitude of variability.

5.1 Seat Back Effect on Variables

No significant differences were found between using a MOD or STD seat-back, and between left and right arms for any measures. Because ROMs were self-selected by participants this measure became a dependent variable of and was subject to reliability assessment. We found that ROM PEAK measure was a viable measure to use evidenced by the >0.74 reliability between all testing sessions.

It was hypothesized that ROM would be greater under the MOD condition, but analysis indicated no significant difference. If anything, it was expected that ROM might increase at least for the MOD condition as participants became more familiar with the movement and acted on the researcher's encouragement to maximise their range of movement. However, the opposite was found; participants actually decreased their ROM from the first to the second session by 3.2%.

It appears that participants may have voluntarily decreased their ROM as the movement became more familiar to them with repeated sets and sessions. This could be explained by the theory of self-optimisation, which refers to the principle that the realisation of a movement pattern may be a result of many constraints that minimise the "costs" to the

system (Sparrow, 1983). Thus, the reduction in ROM may be a consequence of an individual's self-optimisation. In the present study, as the technique became more familiar, participants may have consciously or automatically adjusted their body configuration to reduce the initial range of motion where they were not feeling particularly strong and still meet the task demands. The task required maintaining maximal tension through the full range. The conscious or subconscious realisation that it was difficult to maintain maximal tension at the START of the movement may have resulted in a voluntary reduction in range in order to either protect oneself or to minimise the challenge of movement through that initial range.

Although ROM exhibited a general downward trend across testing sessions, torque measures increased (~15%). Participants likely positioned themselves to generate the greatest amount of tension and, in doing so, limited their degrees of freedom to enable tension to be applied more directly (horizontally and anteriorly away from the line of the torso). This may have meant reduced synergistic control required to eliminate extraneous movements. Because the movement is unique in some of its parameters (e.g. deeper 'untrained' range, variable limb tension, and maximal tension maintenance), some learning was required to produce optimal outputs. These adjustments may have been through altered neuromotor coordination patterns that facilitated muscle group maximal contractions and multiple muscle group activation for pattern stabilization (Laycoe & Marteniuk, 1971; Rutherford & Jones, 1986). The result of this learning could be a decreased total horizontal-abduction range (*Figure 3*). A functional anatomical factor that may help explain this is scapulae 'locking', where the scapulae are isometrically stabilised in partial to full retraction to provide a fixed base of support to aid in leverage pushing away from the body. Subsequently, this could limit both natural retraction and protraction and, therefore, a full ROM. This positioning may have allowed for more distal joints (proximal-to-distal pathway concept, Kibler, McMullen & Uhl,

2012) to assist in the tension generation. Such a strategy would be a fundamental precursor to potentially forming a functional kinetic chain to work more effectively as suggested by Kibler, McMullen & Uhl (2012). With the body working more effectively to meet the task demands it may not be surprising that more work could be done over a reduced ROM with learning.

5.2 Torque Measures.

Providing a peak torque measure is important because it gives a more accurate representation of 'strength' compared to 1-RM testing. This is because isokinetically, an output can be recorded at any point in the movement range as opposed to 1-RM testing recording the successfully completed load at the end of the concentric phase. A broader picture of 'strength' is formed by also recording the total work done. This provides an indication of how torque is maintained throughout the movement range.

Previous studies have demonstrated that isokinetic peak torque and work measurements can be measured reliably for both eccentric and concentric actions. These studies used various limb movements at speeds ranging from 60-180°/s, but no higher than 120°/s for upper-limb movements (ICC's > 0.75; Frisiello, Gazaille, O'Halloran, Palmer & Waugh, 1994; Sole, Hamrén, Milosavljevic, Nicholson & Sullivan, 2007; Tredinnick & Duncan, 1988).

It can be suggested that PEAK measures are most appropriate to use for further analysis as they represent the typical scoring method used in strength and conditioning fitness testing – that is, the best score is normally recorded.

In the present study eccentric PT could be measured reliably, but the poor reliability (0.57) between session 1 and 3 measures suggests that at least two test sessions may be required to obtain a reliable measure of eccentric PT. The eccentric TW measure followed a

similar pattern with the most reliable measurement being obtained in session 2. It was expected that participants would become familiar enough with the pressing motion technique used to yield reliable/consistent peak measures by at least the third testing session. We found that a second session was generally sufficient to yield reliability for eccentric measures. Concentric PT and TW could also be reliably measured with correlations >0.78 across all sessions. A single test session was, therefore, sufficient to obtain a reliable measure of concentric peak torque. This is consistent with the typical optimal loading and emphasis on concentric actions in resistance training and strength testing, but not necessarily in functional strength for contact team sport demands.

5.2.1 Work Done in Initial ROM

The area of particular interest in the torque curves was the range that we presumed was unchallenged in conventional flat-bench bench pressing. Therefore we elected to examine work performed in the initial 5° of ROM. With respect to muscle action, this was the work performed preceding the END of the eccentric action and preceding the START of the concentric action where the shoulder is nearest maximal horizontal abduction. This zone was of interest due to this study's hypotheses that conventional flat-bench bench pressing does not typically permit or encourage resisted movements in this range and, as discussed in Chapters 1 and 2, is an area where injury susceptibility could, possibly, increase.

For IW measures, the best eccentric and concentric reps provided reliable measures to use. A second testing session would be recommended to ensure a reliable measurement, both eccentrically and concentrically, for all measures.

5.2.2 Angle of Peak Torque

For both eccentric and concentric actions the angle of peak torque had questionable reliability with <0.53 correlation between all testing sessions. Due to these correlations and the large confidence intervals for each measure, angle of peak torque was not a reliable measurement for this movement pattern. Further investigation of °PT is required to identify whether this is measurement error, or the angle of peak torque is simply an inconsistent phenomenon. From theoretical models of the length-tension relationship (see Section 2.4 *Figure 4*), there is a sense that angle of peak torque should be a stable phenomenon. These models appear to show an optimal zone of around 50% of the ROM depending on the joint. Most studies that have explored the angle peak torque have done so with single-joint movements. The pressing motion is a multi-joint movement and, to the researcher's knowledge, no studies have looked at °PT in a pressing motion. Eccentric training has been shown to increase muscle fascicle length (adding more sarcomeres in series) to a greater extent than normal strength training (i.e. in the hamstring; Clark, Bryanta, Culgan & Hartley, 2005; Kilgallon et al. 2007; Blazevich, Cannavan, Coleman & Horne, 2007; Brughelli, Mendiguchia, Nosaka, Idoate, Los Arcos & Cronin, 2010; Guex, Degache, Morisod, Sailly & Millet, 2016; Bourne, Duhig, Timmins, Williams, Opar, Al Najjar & Shield, 2016). It has been suggested that increasing muscle fascicle length leads to a °PT at greater joint angles and may be important in reducing muscle strain injury risk (Guex et al. 2016). However, it has also been suggested that other factors may be involved such as mechanical advantage, neural drive, MTU stiffness and regional muscle size. Therefore, given the multi-joint nature of the pressing motion, other factors could explain the variability within and between participants in the present study.

5.2.3 Learning with Isokinetic Testing.

Although the movement used in this study has similarities to gym-based pressing movements, it differs in two ways: (1) The task requires maximal tension with a fixed velocity; and (2) tension produced differs throughout the pressing range. Due to the novel nature of the task some learning was expected. It has been shown that eccentric strength requires some learning in order to produce optimal outputs, which is a factor of neuromotor coordination patterns enabling muscle group maximal contractions and multiple muscle group activation for pattern stabilisation (Laycoe & Marteniuk, 1971; Rutherford & Jones, 1986). From the results, PT and TW increased by ~15% across the three sessions, which, potentially, shows an increased ability to apply/maintain maximal tension throughout a full range. This is more likely due to increased neuromotor coordination rather than a physical/muscular adaptation due to the short window (7-14 days) in which testing was conducted and no training intervention being given.

5.3 Eccentric and Concentric Ratio

There were differences between eccentric and concentric peak torques but the ratios were smaller than the 1.3 to 1.5 extent suggested in the literature (Durand, et al. 2003). It was expected that our study would show similar results, however, the eccentric : concentric ratios were 1.15 and 1.17 on the second and third testing session, respectively. Several factors could help to explain why the eccentric to concentric ratios were lower for this novel movement. One explanation could be the difference in loading requirements with our pressing motion technique, which required constant pushing tension with a constant controlled velocity. Traditional flat bench press involves a loaded bar held vertically above the chest (i.e., isotonic contractions), while lying in a supine position. Lowering at a self-paced velocity until the bar contacts the chest is, intuitively, much easier than pushing away in the counter

direction. Underlying factors, such as passive MTU tension and mechanical advantage, are likely more optimal in the eccentric action of the latter loading condition than during the movement employed in the present study.

5.4 Potential Implications

Difference in isokinetic torque measures were expected to favour the MOD seat-back condition, however, they did not. There appears to be no measurable difference between seat-back conditions in torque measures in the present study. While there may be no advantage in torque production and work outputs between conditions, there also appears to be no functional or safety reasons not to, at least, test and potentially, train, through a full ROM. This is based on participants reporting no muscle soreness or injury post-testing.

As discussed, individuals may instinctively attempt to shorten the distance through which the limb/object of resistance must travel in order to optimise the movement. This likely enables athletes to lift heavier loads through the pressing motion. Training focus could be shifted from absolute load and, instead, focus on strengthening through a larger range of motion. External apparatus that restricts or alters natural (unrestricted/uninhibited) movement patterns (kinetic chains) needs to be critically examined as part of a strength and conditioning plan. The only real counter-arguments may be convenience, tradition and the transfer ability of full range strengthening.

There was no significance shown between limbs, indicating that reported arm dominance had no bearing on torque measures. This may mean that either limb could be measured and assessed as reliable, without having to assess the other limb, when measuring overall pressing 'strength'.

5.5 Future considerations

The present study had several limitations and delimitations that should be considered along with any further research considerations. The training status of participants varied; some trained (outside of the study) differently than others, despite being categorised as resistance trained. Although participants were asked to keep external factors consistent before and between testing sessions, it was difficult to control participants' previous exercise and diet in the days leading into testing. Additionally, the researcher had no control or measure of how motivated participants were to perform.

As this study's sample size was small, this would likely have yielded low statistical power for identifying differences between conditions (i.e. analysis of variance) and requires some caution when considering some of the research hypotheses. It should be noted that the main focus of this study was measurement reliability and, for that purpose the sample size was appropriate. In future studies, sample size would be a factor to carefully consider in order to enhance statistical power when analysing condition effects with the unilateral pressing technique on the Biodex. This study provides a basis for which future studies using the novel pressing movement can perform power analysis reliably.

The Isokinetic dynamometer (Biodex System 2) was utilised and an angular velocity of 90°/s was chosen in an attempt to replicate the typical cadence of a bench press repetition (González-Badillo & Sánchez-Medina, 2010). The Biodex dictated isokinetic measurements were unilateral, however, the study attempted to mimic a bilateral pressing motion, with the use of an elastic resistance on the opposing arm.

5.5.1 Suggested Methodological Changes

The elastic resistance applied to the arm opposing the lever-arm resistance provided challenges. The reasons for the opposing arm still acting to maintain bilateral symmetry were to: (1) Avoid excessive trunk rotation; and (2) provide a movement pattern that mimicked the barbell bench-press being scrutinised. It had been intended that the physical setup would allow for calculation of the elastic co-efficient of the elastic resistance, but departmental resource limitations prevented this coming to fruition. From observation, the contralateral movement appeared to aid in torso alignment as the arms moved horizontally (concentric action) away from the body. The elastic resistance/tension decreased as the arm horizontally abducted (eccentric action), which, in some cases, led to the trunk rotating slightly (shoulder with elastic resistance moving forward away from the seat-backing). In future: 1) The co-efficient could be measured and adjusted accordingly for each participant; 2) a device to replicate the resistance/tension of the Biodex arm could be utilised; and 3) other means of eliminating or minimising torso rotation could be trialed.

5.5.2 Further Research Implications

This study has established that isokinetic torque and joint angle can be measured reliably using a novel movement pattern and a modified Biodex setup. This paves the way for exploring different training interventions on pressing motion torque profiles. It may be that certain training methods may alter the theoretical optimal length-tension relationship and eccentric-concentric torque ratio. Durand, et al. (2003) demonstrated that eccentric strength was 30-50% higher than concentric strength, yet the present study failed to show this magnitude of difference. It would be worthwhile to investigate whether these ratios could be modified through training interventions and enhanced shoulder ranges of motion. It would

also be important to assess whether using a full range of motion is safe when training chronically.

To improve such a training intervention study, kinematics and muscle activity could also be considered, and alternate measures of bar velocity (e.g. through linear position transducers) could be utilised with traditional bench-pressing exercises. A limitation of measuring only torque profiles and not successfully identifying angle of peak torque, is that torque and work are the only source of quantifiable information. The process or technique by which these outputs are produced and modified could be quite different. A kinematic approach would help understand how body configurations might influence output measures (e.g. PT) and electromyography (EMG) may provide a better understanding of the patterns of muscle activation. This could help further explore the hypothesis that the width of the flat-bench can influence scapulae mobility. Differences shown here could provide more information on the pressing motion and provide a link towards exploring possible performance and injury relationships.

5.6 Conclusion

This thesis was primarily a reliability study, the data of which will be useful for attempts to explore a modified bench approach. The novel pressing motion technique employed in this study can be used for reliably testing isokinetic strength of both eccentric and concentric actions. This is shown by peak torque and work done measures yielding ICC's > 0.68. While MOD and STD seat-back conditions did not influence peak torque or work and, not powered or intended to necessarily find such differences in this study, have demonstrated that participants, during testing, can safely press through an enhanced range. This is indicated by, participants reporting no muscle soreness or injury post-testing. There is, therefore, no

apparent reason why the pressing movement must be constrained when testing in the strength and conditioning environment.

Given the rise in the incidence of shoulder injuries in a contact sports, such as rugby union, following the advent of the professional era, it is important to recognise that this may be a factor to consider. Injury has a direct effect on players and, therefore, it seems important to explore potential causalities.

In the present study the background context was that the traditional flat bench barbell bench-press may actually be of hindrance or harm, rather than of help, to performance. The bench press exercise is utilised based on a broader perceived reliance on strength and conditioning practices to aid playing performance.

This study sought to challenge the prevalent strength testing and prescription paradigm and add to the field of functional resistance training. It is suggested that there may be modifications that would transition constrained movement patterning not specific to the sport, to movement patterning that is more 'naturalistic' (unrestricted/uninhibited) and specific to the sport it is prescribed to improve performance in such sport.

6.0 Appendix

6.1 Participant Information Sheet

Participant Information Sheet

Study title:	Does the bench press condition for failure? Effect of a modified bench on torque-angle profiles of the pressing motion	
Principal investigator:	**Name:** Phil Handcock **Department:** School of Physical Education Sport and Exercise Sciences **Position:** Senior Lecturer	Contact phone number: 03 4795 025

Introduction

Thank you for showing an interest in this project. Please read this information sheet carefully. Take time to consider and, if you wish, talk with relatives or friends, before deciding whether or not to participate.

If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

What is the aim of this research project?

The theory being tested in this project is that conventional flat bench press training could reduce 'normal' scapula movement and thereby natural shoulder girdle movements. The width of the conventional flat bench press exercise can obstruct and restrict the scapulae movements, movements that are a key part of the coordinated pressing movement sequence. The aim of this masters is to observe the effect a modified (uninhibited scapula) bench setup has on torque-angle profiles of the pressing motion. Among the potential implications from this study are providing the evidential basis for finding alternative approaches to improving and measuring upper body functional strength. Practical considerations may be of interest to any exercise practitioner concerned with the health and well-being of their respective clientele.

Who is funding this project?

Internally funded by the School of Physical Education Sport and Exercise.

Who are we seeking to participate in the project?

Participants (n=30) will be recruited from a wider Dunedin population. The researcher is seeking a mixture of resistance-trained and untrained participants to provide participants with a range of resistance training and functional experiences.

You may be excluded if in the presence of any previous shoulder girdle/associated tissue or bone surgeries or major injury that still requires treatment/rehabilitation or may be aggravated by strenuous exercise. Participants will also be excluded if they report any current neck, spine and/or any neural complications.

If you participate, what will you be asked to do?

You will complete screening to ensure that they meet the entry criteria and will be provided with information on the testing and protocols and asked to provide informed consent.

Participants will complete a familiarisation session (30 mins) and then three further testing sessions (3 x 45 mins with 2-7 days between sessions).

Familiarisation Session 30mins	2-7 days	Testing Session 1 45mins	2-7 days	Testing Session 2 45mins	2-7 days	Testing Session 3 45mins

You will perform a single arm pressing movement (both arms – see figure below) using the Biodex System 2 Isokinetic Dynamometer (Biodex Medical Inc., Shirley, NY) with a modified lever arm at 90°/s.
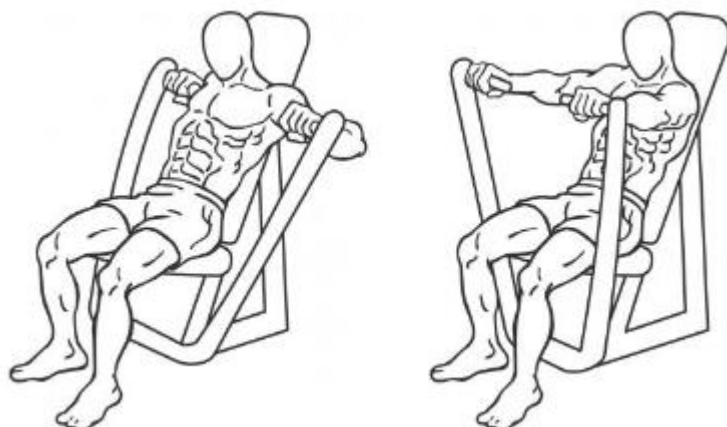
You will complete a 10 min warm up with stretching prior to testing and a 5 min warm down with stretching after testing.

During testing you will be encouraged to perform 5 repetitions under constant maximal effort (attempting to push the lever arm away from the body at all times). You will repeat the 5 repetitions 3 times with 5 min rest between each bout for each arm.

Is there any risk of discomfort or harm from participation?

Potential risks are minimal. The single arm pressing movement will involve maximal effort through a full range of motion during concentric actions and during eccentric loading. You may experience some soreness or fatigue during the testing, and following the completion of the testing (i.e. later in the day, the next morning, up to and including 72 hours post-testing). However, this discomfort will not differ from what would likely be experienced during the course of a normal weights training session and should not interfere with your normal activities.

What specimens, data or information will be collected, and how will they be used?

Your name, contact details, age, ethnicity, height, weight and sporting and resistance training history will be collected at the initial familiarisation session.

What about anonymity and confidentiality?

Minimal personal information will be collected. This information will be stored in a locked filing cabinet in the office of Phil Handcock (Room 102, 665 Cumberland St). Only Dr. Handcock and the student researcher (Brett Harris) will have access to this data. Phil Handcock will retain data and take responsibility for disposing of this data in accordance with Otago University procedures on archiving data.

If you agree to participate, can you withdraw later?

You may withdraw from participation in the project at any time and without any disadvantage to yourself.

Any questions?

If you have any questions now or in the future, please feel free to contact either:

Name: Brett Harris **Position: MPhEd Candidate** **Department: School of Physical Education Sport and Exercise Sciences**	Contact phone number: **0278149449**
Name: Phil Handcock	Contact phone number:

Position: Supervisor	03 479 5025
Department: School of Physical Education Sport and Exercise Sciences	

This study has been approved by the University of Otago Human Ethics Committee (Health). If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (phone +64 3 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

6.2 Consent Form

Does the bench press condition for failure?
Effect of a modified bench on torque-angle profiles of the pressing motion?

*Principal Investigator: Phil Handcock (*phil.handcock@otago.ac.nz)

CONSENT FORM FOR PARTICIPANTS

Following signature and return to the research team this form will be stored in a secure place for ten years.

Name of participant:………………………………………..

1. I have read the Information Sheet concerning this study and understand the aims of this research project.
2. I have had sufficient time to talk with other people of my choice about participating in the study.
3. I confirm that I meet the criteria for participation which are explained in the Information Sheet.
4. All my questions about the project have been answered to my satisfaction, and I understand that I am free to request further information at any stage.
5. I know that my participation in the project is entirely voluntary, and that I am free to withdraw from the project at any time without disadvantage.
6. I know that as a participant I will be required to attend on 4 occasions (30 min each) and that the three final sessions will involve a maximal strength test using a single arm pressing movement.
7. I understand the nature and size of the risks of discomfort or harm which are explained in the Information Sheet.

8. I know that when the project is completed all personal identifying information will be removed from the paper records and electronic files which represent the data from the project, and that these will be placed in secure storage and kept for at least ten years.

9. I understand that the results of the project may be published and be available in the University of Otago Library. I agree that any personal identifying information will remain confidential between myself and the researchers during the study, and will not appear in any spoken or written report of the study.

10. I know that there is no remuneration offered for this study, and that no commercial use will be made of the data.

Signature of participant: Date:

6.3 Pre-screening Questionnaire

Name:_____

Contact details:

Phone: _____

Email: _____

Age (Yrs.):_____

Ethnicity: (Mark the space or spaces which apply to you)

O New Zealand / European

O Chinese

O Māori

O Indian

O Samoan

O Tongan

O Niuean

O Cook Island Maori

O Other, please state: _____ (e.g. Dutch, Japanese, Tokelauan)

Height (m):_____

Weight (kg):_____

Sporting history:

Contact:

Sport_____ Level_____ Yrs._____

Sport_____ Level_____ Yrs._____

Throwing:

Sport_____ Level_____ Yrs._____

Sport_____ Level_____ Yrs._____

Resistance Training history:

Year's trained_____

BB Bench Press use:

Per week: _____ 1RM:_____ XRM_____

Upper Body Focus:

Per week: _____

Modes + Times/week:

_____

_____

Injury + Surgery History (Upper Body):

What:_____

When:_____

What:_____

When:_____

What:_____

When:_____

(Following section for researcher only)

Foam Alignment:

Power Head height:

Chain Length:

Session times:

Familiarisation_____

Rest period_____

Testing 1_____

Rest period_____

Testing 2_____

Rest period_____

Testing 3_____

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