SCHEDULE 2
THE PROJECT

‘Biomechanics of the Rugby Scrum’

Research Project for the International Rugby Board (acting through its operating entity IRFB Services (Ireland) Limited)

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Project Title:  Biomechanics of the Rugby Scrum

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Note:
Any references in this document to “IRB” shall mean IRFB Services (Ireland) Limited the operating entity of the International Rugby Board.
‘Biomechanics of the Rugby Scrum’

Competitive scrummaging is a unique and valued component of rugby union. Effective scrummaging requires a pack of forwards to produce forceful and coordinated actions to ensure dominance over the opposition to provide a platform for launching attacks and to disrupt opposition ball. Unfortunately, due to the physical nature of this phase of play there may be associations of the scrum with chronic degenerative injuries to the spine and on very rare occasions catastrophic cervical spinal injuries do occur.

Despite this, little is known about the forces and motions involved in rugby scrummaging, with very little objective data being collected since the advent of professionalism over ten years ago. A need has been identified to re-visit the biomechanical demands experienced by players during the rugby scrum, particularly during scrum engagement, with a view to understanding more about how to maximise performance and how to manage injury risk.

This research programme will investigate the biomechanics of rugby scrummaging with a view to delivering objective data regarding the techniques and practices required to perform effective and safe scrummaging. The testing will involve forward packs from many different levels of the game (e.g. school, academy, women, community club, elite club and international) from as many different parts of the rugby playing world as possible. Information will be obtained on the individual and combined forces being generated during scrum engagement and the secondary shove as well as the body motions which accompany effective and safe scrummaging. The testing will look at how the measured variables alter due to different scrum engagement and binding techniques and will also highlight any differences between machine-based scrummaging and live scrummaging against an opposition pack.

The Project Outcome Objectives are to:

- To establish the biomechanics of different scrummaging techniques to assess potential injury risk
- To identify playing, coaching and match official techniques that provide for effective scrummaging with a reduced risk of serious injury to players
- To provide data and information to enable Law amendments to be considered in relation to the scrum

This research will provide information on the biomechanical demands placed on players during the normal process of scrummaging under different conditions. From this, it will be possible for individual players, coaches and referees along with governing bodies to make informed decisions on how best to perform effective scrummaging whilst appropriately managing any reasonable risk involved.
1. EXECUTIVE SUMMARY

- **Context:** Competitive scrummaging is a valued component of rugby union but this phase of play has been associated with chronic injuries and a disproportionate number of serious injuries to players.

- **Problem:** A need has been identified to re-visit the biomechanical demands experienced by players during the rugby scrum, particularly during scrum engagement.

- **Description:** This document sets out a programme of work to investigate the biomechanical demands of scrummaging in two main phases. Phase 1 will primarily deliver information on machine scrummaging and will further investigate opportunities for assessing live scrummaging. Phase 2 will investigate the biomechanics of live scrummaging.

- **Purpose:** The primary aim of this programme of work is to provide accurate, up-to-date information on the biomechanical demands experienced by rugby forwards during scrummaging with a view to providing objective evidence on techniques leading to effective and safe scrummaging.

- **Outcomes:**
  - To establish the biomechanics of different scrummaging techniques to assess potential injury risk
  - To identify playing, coaching and match official techniques that provide for effective scrummaging with a reduced risk of serious injury to players
  - To provide data and information to enable Law amendments to be considered in relation to the scrum

- **Significance:** It is envisaged that this programme of work will provide valuable information to the International Rugby Board (IRB) and other stakeholders regarding the precise nature of the biomechanics of rugby scrummaging. The results will provide coaches and players with information regarding which techniques lead to more effective scrummaging and provide the IRB with objective data on which to help base decisions regarding future possible interventions / law changes to improve the safety of scrummaging and to benefit the long-term health of rugby players.
2. PROJECT GROUP: PREVIOUS TRACK RECORD

Within the School for Health at the University of Bath, the primary focus of the ‘Integrative Human Performance’ group is to identify the parameters limiting human locomotor activity and investigate interventions to improve function during normal daily living and athletic performance. The movement-related research of this group relocated to a newly renovated suite of laboratories and offices in September 2007. This £1 million investment in physical infrastructure now combines with the group’s state-of-the-art research instrumentation which includes an automatic 3-D motion analysis system (Coda CX-1), synchronised to high-speed video, force plate and telemeteric EMG systems.

Within rugby union research Dr Grant Trewartha has conducted research studies focusing on the biomechanical aspects of individual skills including goal kicking (Bezodis et al., 2007) and lineout throwing (Trewartha et al., 2008) as well as technique interventions for injury prevention during side-step movements (Trewartha et al., 2007). Dr Trewartha has also previously researched the development of innovative technologies for the automatic measurement of human motion (Trewartha et al., 2003; Yeadon et al., 2004). In collaborative research studies, Dr Trewartha and Dr Keith Stokes have coordinated studies investigating the measurement and evaluation of the physical demands of elite rugby union (Roberts et al., 2006; Roberts et al., 2008), the epidemiology of rugby injury in school-level and academy-level rugby union (funded by the RFU, e.g. Palmer et al., 2007), and impact forces during tackling (Trewartha & Stokes, 2003). They also coordinate the RFU injury surveillance project for club rugby (2008-2012). Dr Stokes has also received funding from the Ministry of Defence for an ongoing project designed to identify some of the key risk factors for musculoskeletal injury during basic infantry training.

Dr Mike England is the RFU Community Rugby Medical Officer, responsible for delivering a World Class sports medicine programme for community rugby union including research in relation to injury prevention and policy in relation to player welfare.

Structural Statics specialises in automated and autonomous acquisition of high quality data related to structural performance. In this project the company will apply impact force monitoring techniques previously developed by the company, based on the company’s smart DDM technology and used to monitor (impact) forces applied to structures as diverse as warships at sea, bridges subject to impact, pylons affected by cable failure, runway lights struck by aircraft landing, and advertising panels affected by train induced wind loading.

Alan Kenchington has been involved in the design of sophisticated structural, environmental and geotechnical monitoring systems for more than 25 years. He has been responsible for many of the innovations that led to Structural Statics Ltd winning the Queens Award for Enterprise in 2003.
3. BACKGROUND

3.1 Rugby Injury

The injury incidence figures reported in rugby union cohorts are often substantially higher than those reported in the majority of other team ball sports. For example, injury incidence per 1000 hours of player match exposure has been found to be 58 for international rugby union (Brooks et al., 2005a) compared with 39 in club-level rugby league (Hodgson-Phillips et al., 1998), 17 for international soccer (Junge et al., 2004) and only 2.8 (training plus matches) for international cricket (Orchard et al., 2002).

The limited longitudinal data which exists also suggests that the incidence of rugby injury has increased since the advent of professionalism (after the 1995 World Cup), certainly at the professional level. The Australian Wallabies saw the injury rate rise post professionalism (1996-2000) to 74 injuries/1,000 player-hours from the pre-professionalism injury rate (1994-1995) of 47 injuries/1,000 player-hours (Bathgate et al., 2002). This increase in injury rate has been in part attributed to the increased physicality of the participants and the exaggerated confrontational style of play, and it is likely these changes have filtered down to the amateur/community/youth levels of the game. Such drastic changes to the nature of the game suggests a need to update collective understanding of the precise physical nature of rugby events to gain a better understanding of how close to injury tolerance limits rugby players are operating.

Many elements of rugby result in contact situations between individuals (e.g. tackles) or groups of individuals (e.g. scrums). The incidence of very serious injuries during such phases of play is disproportionately high and so it is important that research is performed to analyse the biomechanics of these events with the aim of providing an evidence base from which realistic interventions can be suggested to reduce the risk of serious injury.

3.2 Rugby Scrum Injury

The rugby union scrum is still a genuinely competitive phase of the game, where offensive teams attempt to establish a stable platform from which to attack and defensive teams attempt to disrupt this platform. The scrum is characterised by a high initial impact during the engagement of the opposing packs with sustained opposing forces being exerted during the entire time period.

Overall, the incidence of scrimmaging injuries (10 injuries/1,000 player-hours) (Brooks et al., 2005c) and the proportion of overall injuries from scrimmaging (2%: Bathgate et al., 2002; 6%: Brooks et al., 2005b; 8%: Targett, 1998) are relatively small compared with other injury mechanisms. However, while the overall risk of sustaining a scrimmaging injury in a rugby union match is not high, the propensity for injury (risk per scrum event) has been rated as high (Fuller et al., 2007). Front-row forwards are particularly susceptible to scrimmaging injuries, with 23% of front-row injuries in a professional cohort sustained in the scrum (Brooks et al., 2005c). Consequently a large proportion of the scrimmaging injuries were sustained by the front-row (91%), with tight-head props (45%) receiving a greater proportion compared with loose-heads (27%) and hookers (25%) (Brooks et al., 2005c).

According to Brooks and colleagues (2005b,c), calf muscle injuries were the most common scrimmaging injury and calf muscle injuries and shoulder injuries caused the greatest number of days absence in a cohort of professional rugby union players. Neck injuries made up a smaller proportion of the scrimmaging injury burden (15%) (Brooks et al., 2005c), however, the scrum was responsible for a high proportion of front-row spinal injuries (41% of cervical; 56% of thoracic; 71% of lumbar). The reason for this front-row susceptibility to spinal injuries is likely to be the repeated high forces experienced by these players (Quarrie and Wilson, 2000), particularly during the scrum engagement.
In extreme circumstances, a sports injury can result in permanent paralysis or a fatality. Spinal cord injuries resulting in catastrophic consequences have caused significant concerns in collision sports, such as American football (Torg et al., 1987) and rugby union (Quarrie et al., 2002). Although the incidence of injuries due to scrummaging in rugby union is relatively low, the unique rugby union specific action of competitive scrummaging has been associated with catastrophic cervical spine injuries (Scher, 1982; Silver, 1992; Secin et al., 1999).

In a review of the available data, scrums were implicated in approximately 40% of all serious cervical spine injuries in rugby union (Quarrie et al., 2002), followed by the tackle (36%), although these proportions vary between studies in different countries (Quarrie et al., 2002).

Reports on the relative risk of a serious spinal injury in young and adult players appear contradictory (Quarrie et al., 2002), with some reporting younger players to be at higher risk (Bottini et al., 2000) and others suggesting adult players are at relatively higher risk (Kew et al., 1991). The risk factors for each of these populations may also vary. Spinal injuries in young and schoolboy rugby players have been attributed mainly to a lack of maturity in skeletal and ligamentous structures (Silver, 1979). Adult players may be susceptible to such injuries due to the greater size and strength of players and the more aggressive nature of the senior game (Quarrie et al., 2002). A mismatch in skill, experience or strength has been suggested as a risk factor for injury in the scrum, with the risk of injury being equal across the stronger and weaker team. Wetzler et al. (1998) found evidence of a mismatch of some type in 25% of all scrum injuries.

The front-row experience the vast majority of serious cervical spinal injuries in the scrum, with the hooker being particularly susceptible (78%: Wetzler et al., 1998; 73%: Secin et al., 1999). The vulnerability of the hooker was attributed to a number of factors, including the wrapping of their arms around props with the effect he/she cannot control or dissipate forces of engagement, the reliance on the props for support during engagement and formation, and the inability to adjust upper body position to react to improper engagement.

It is not clear whether the incidence of serious cervical spine injuries has increased or decreased over the last 30 years due to a lack of accurate exposure data (Quarrie et al., 2002). In a 2-year prospective study of professional club rugby, Fuller et al. (2007b) reported no instances of catastrophic spinal injury but a total of three career-ending injuries. Any increase in the incidence of such injuries for example might also be due to improved diagnosis, treatment or reporting. In any case these injuries remain extremely rare occurrences with estimates of the incidence of cervical injuries causing tetraplegia or quadriplegic varying between 2.3/100,000 players per year (Quarrie et al., 2002) and 6.5/100,000 (Rotem et al., 1998) and those causing death or tetraplegia at 10/100,000 players per year (Maharaj and Cameron, 1998). Despite this fact, preventative strategies must be prioritised towards injuries causing permanent disability or death (van Mechelen, 1997) due to the devastating consequences of such injuries.

The potential for long-term damage is even greater. Fuller et al. (2007b) concluded that there was a high risk of noncatastrophic spinal injury during both scrummaging and tackling during matches and from weight-training activities. Front-row forwards are particularly prone to premature degenerative disease of the cervical spine (Scher, 1990; Broughton, 1993; Berge et al., 1999), which may result in osteoarthritis and functional impairment (Scher, 1990). The repeated microtrauma experienced during scrummaging is a likely contributory cause (Berge et al., 1999). Therefore, understanding and reducing the forces impacting on the cervical spines of the front-row forwards during scrummaging may have a positive influence on the long-term health of these players following retirement from playing.
In summary, the scrum is associated with a relatively low incidence of injuries, but occasionally results in serious injuries, in particular to the cervical spine. While the tackle phase has emerged as the most common cause of all cervical spine injuries, there are still concerns raised regarding the safety of the scrum, and particularly scrum engagement, and the risk of serious spinal cord injury (SCI). The relatively "controlled" environment of the scrum is a phase of play in which it should be possible to intervene to reduce injury occurrence, either through modifications to player technique, coaching practices or laws. Because of this, the scrum remains an important area of rugby union to research with a long term goal of injury reduction.

3.3 Rugby Scrum Injury Mechanisms

A number of injury mechanisms which may contribute to cervical spine injury in scrummaging have been suggested. Dick et al. (2003) stated that the most common mistake was for players to engage the scrum with slight flexion of the neck. This results in an elimination of the normal cervical lordosis so that during a mistimed or misdirected scrum engagement the load is applied to the flexed cervical spine rather than across the shoulders. Work from Milburn (1990) with forward packs scrummaging against an instrumented machine has confirmed that the forces experienced on engagement are sufficient to destabilise the spine. McIntosh (2003) found the typical pattern of loading relating to neck injury was axial loading accompanied by a bending moment, a loading type observed during scrum engagement. The orientation of the applied load, the presence of constrained motion and the amount of energy absorbed have been found to determine the failure mode of the cervical spine, these factors all being relevant to the scrum situation. Milburn (1993) also highlighted that the bound rugby scrum places the cervical spine at risk of injury. He identified that “charging in” or misalignment of the head during engagement may result in injury, either via hyperextension (popping out) or more commonly from compression and hyperflexion of the cervical spine.

3.4 Biomechanical Analyses of the Rugby Scrum

The biomechanics of rugby scrummaging has been investigated previously, both for injury reduction/prevention (e.g. Milburn, 1990) and performance profiling (e.g. Quarrie & Wilson, 2000) purposes. Milburn (1990) investigated the forces experienced by front row forwards scrummaging on an instrumented scrum machine. The engagement phase was characterised by large impulsive forward forces which lasted about 1 s, acting to stop the opposing forward motions; this was followed by a drop in the force due to ‘compression’ of body tissues and the reorientation of body positions. The magnitude of forward forces at engagement ranged from 3470 N (novices) to 7980 N (international). The observed high forces / impulses were due to the high masses and high speeds involved, and therefore assumed to be due mainly to momentum generated by speed of engagement rather than active muscle action on impact. Vertical engagement forces were found to be downward for most groups (opposed by leg extension action) which would heighten the risk of collapse particularly if misalignment, mismatches in experience or strength, or pulling down on opposites was evident. Lateral forces during engagement were identified as being inefficient and, over the long term, a likely cause of premature degeneration of the cervical spine. Also, during the secondary shove phase lateral forces were viewed as inefficient technique and highlighted limitations of particular formations or binding combinations. Milburn concluded that forces on engagement approached or exceeded the threshold of injury for the spine in flexion.

Milburn & O’Shea (1994) further investigated the forces experienced by front row players using the staggered or sequential scrum formation. Kinetic data were collected by three force plates and summed to provide the total forces acting on the front row under different conditions. They found that two variations of sequential engagement did
not substantially reduce the engagement forces experienced by individual front row players. Further, the staggered formation increased the duration of the scrum as well as the variability of lateral forces acting on the front rows, leading to reduced scrum stability. This study concluded that reduced risk of injury may be achieved more easily through appropriate coaching rather than through modification of scrummaging techniques and laws.

Quarrie & Wilson (2000) presented a model of the ability to produce force in the scrum based on the anthropometric, strength and power characteristics of the player and the player's body position during scrummaging (post-engagement) against an instrumented machine. Their results suggested the need for scrum packs to develop technique and coordination as a unit to maximise scrummaging force.

In summary, previous work regarding the biomechanics of rugby scrummaging provides a starting point for future research but several limitations in the current literature should be acknowledged. Previous studies have generally analysed a small number of scrums, insufficient to permit robust statistical treatment to detect changes or relationships. Also, only machine scrummaging has been studied with little information on how measured variables would vary on different machines. Lastly, from this work in machine scrummaging interpretations in terms of recommended safety practices to reduce injury risk have likely been extrapolated too far.

3.5 Rugby Scrum - Preventive Measures

A number of recommendations have been made to try and reduce the occurrence of serious cervical spine injuries during scrummaging and in recent decades law changes have been introduced to try and reduce the risk of serious injury during the scrum phase. These law changes include alterations to permitted binding, changes to replacement laws, altered procedures of scrum engagement (particularly the crouch-touch-pause-engage protocol) and greater involvement of touch judges in highlighting dangerous play. For instance, the laws of the game now state that each player in the front row and the replacement should be suitably trained and experienced, although the difficulty in establishing what constitutes “trained and experienced” has been identified (Quarrie et al., 2002).

Additional initiatives have been suggested, including the use of weight-based categories in junior rugby, the graded development of scrum technique, and sequential engagement methods (e.g. Milburn, 1990). Some authors have simply recommended appropriate education programmes for younger players in the use of correct technique (Dick et al., 2003), whereas others have advocated the implementation of adapted engagement rules throughout all levels of the game (McIntosh, 2003). Indeed, the evidence available would suggest that the implementation of education programmes such as Rugby Smart (NZRFU) (Quarrie et al., 2007) and Rugby Ready (IRB) may be very successful in reducing catastrophic scrum-related injuries. However, the extent to which player/coach/referee education alone can assist in reducing long-term health problems is difficult to evaluate.

McIntosh (2003) recommended that injury prevention measures should be directed at laws, law enforcement and skill development. Moreover, Yeo (1998) stated that there was a tendency for reduced injury occurrence following law changes even though more evidence was required before a definite conclusion could be made. This nevertheless highlights that there is a reasonable possibility that law or technique alterations to bring about changes in scrum engagement practices may be an appropriate avenue to attempt to reduce injury occurrence. Understanding how scrummaging performance can be improved under specific conditions (i.e. under different law regimens) is an important step in the process of establishing safe and effective scrummaging practices.
4. OVERALL RESEARCH PROGRAMME

4.1 Aims & Objectives

The guiding aim of this research programme is to provide the rugby community with objective data regarding the biomechanical demands of rugby scrummaging with a view to establishing safe scrummaging techniques. This information will be obtained from participants at various levels of the game and will also be obtained for various scrummaging techniques.

The data produced by this research programme will provide a foundation on which future coaching, refereeing, equipment and law modifications relating to the scrum phase of play can be considered and evaluated against in order to improve scrummaging performance and allow the management of scrum-related injury risk.

The Research Outcome Objectives are to:
- To establish the biomechanics of different scrummaging techniques to assess potential injury risk
- To identify playing, coaching and match official techniques that provide for effective scrummaging with a reduced risk of serious injury to players
- To provide data and information to enable Law amendments to be considered in relation to the scrum

The research objectives are to:
- Provide a description of the pressure and force characteristics of rugby scrummaging against a scrum machine
- Characterise the differences in pressure and force characteristics of rugby scrummaging due to playing level and engagement technique
- Describe the motions and accelerations of individual players and the combined pack during machine scrummaging
- Characterise the biomechanical demands of live contested scrummaging, including pressure, acceleration and motion data
- Reference the obtained biomechanical data to injury threshold data for specific anatomical structures to assess the injury potential of normal rugby scrummaging

4.1 Research Approach

The research programme will be separated into two distinct research projects / phases:

**Phase 1** – Characterising the biomechanical demands of machine scrummaging (start date: 1 March 2010, 12 months duration)

**Phase 2** – Characterising the biomechanical demands of live scrummaging (anticipated start date: 1 March 2011, 24 months duration)

Phase 1 work will concentrate on analysing scrummaging against instrumented scrum machines and will provide data on overall impact forces and pressure distribution at the contact interface as well as combined and individual motions of the players involved in the scrum. Phase 1 will also include preparatory work to investigate potential measurement solutions to be employed in Phase 2, the analysis of live scrummaging.
Phase 2 will follow sequentially and the final study design / protocol will need to be informed by the findings of Phase 1. Nevertheless, Phase 2 will focus on obtaining data on the biomechanical characteristics of live scrummaging.
5. PHASE 1: The Biomechanics of Machine Scrummaging

5.1 Aims & Objectives
The aim of Phase 1 is to further understanding regarding the biomechanical demands of scrummaging in contemporary rugby union through an analysis of the impact forces and body motions observed during scrum engagement and secondary shove against instrumented scrum machines. A further aim of this project is to inform the protocol for analysing the biomechanical demands of live scrummaging (Phase 2).

The objectives of this phase are to:

- Record axial, vertical and lateral impact loads experienced during scrum engagement and secondary shove with an instrumented scrum machine
- Obtain pressure distribution data across the contact interface during scrummaging against a machine
- Obtain standard and high-speed video footage of scrum engagements from multiple perspectives, synchronised to the force and pressure data, to perform qualitative and quantitative analysis of player motions during the engagement sequence
- Associate scrum engagement forces with proposed injury mechanisms and available injury thresholds relating to chronic degenerative conditions
- Help formulate the strategy for future research in scrum engagement by performing a comprehensive needs analysis via literature reviewing and widespread consultation with stakeholders in the rugby and research communities
- Obtain pilot data to determine the most appropriate technologies to investigate the biomechanics of live contested scrummaging in Phase 2 (e.g. accelerometers, pressure measurement, etc)

5.2 Programme of Work
Experimental Design
This project will employ a cross-sectional experimental design. The forward packs will be selected so as to provide representation from various levels of the rugby playing population, including youth, women, amateur and professional. Sufficient forward packs will be assessed to permit robust statistical treatment of the data within a group design. At most levels analysed (school, academy, women, community club) at least six teams in each category will be analysed. In other levels (elite club, international) every effort will be made to add teams to the data pool. A total of approximately 36 teams will be tested to allow meaningful between-group (playing level) or within-group (engagement technique) differences to be detected.

Sample size calculations have been performed based on existing evidence from scrum machine data, assuming a factorial between-within design:

Basis of sample size calculation: To allow the identification of differences in impact forces due to playing level (between factor, 6 levels) and due to scrum engagement technique (within factor, 3 levels) a factorial between-within design is utilised. The sample size calculation has been performed (G*Power software, version 3.0) using the following criterion, with effect size estimated using the peak force data of Milburn & O’Shea (1994):

Mean sample 1 (standard engagement) = 5882 N;
Mean sample 2 (sequential engagement) = 4833 N;
Combined standard deviation (estimated) = 1000 N.

Therefore, estimated Effect size = (Mean1 – Mean2) / SD = (5882-4833)/1000 = 1.05
α error probability = 0.05
Power (1-β error probability) = 0.8
Number of Groups = 18 (e.g. 6 playing levels x 3 engagement techniques)

An a priori sample size calculation for an ANOVA with repeated measures and within-between interaction results in a total sample size = 36 with an actual power = 1.00.

Therefore, the required number of samples per condition (teams in any given playing level) = 6.

Experimental Procedures

Selected forward packs will perform multiple scrum engagement trials on two occasions, one session primarily focussing on the influence of engagement technique and one session focussing on the influence of scrum machine type and resistance settings.

All experimental trials will be performed in an outdoor environment on dry natural turf. Data acquisition will be completed during simulated normal training sessions for each pack. Participants will be attired in their own rugby boots, socks, shorts and short-sleeve tops or custom-made binding tops to aid analysis. Following appropriate warm-up drills each pack will scrummage against an instrumented scrum machine.

For the first session, the scrum machine will be configured to standard positions appropriate for the size of the pack and using standard resistance levels. A number (24-30 trials) engagements with sustained shove will be completed. A series of trials (minimum of 8) will be completed using normal binding and engagement (crouch-touch-pause-engage) techniques. The remainder of trials will introduce a select number of alternate engagement conditions, with coaching in these alternative techniques provided by an experienced scrum coach prior to the trials. Alternative conditions to be analysed will include ‘passive engagement’ and ‘touch-crouch-pause-engage’. It is recognised that multiple trials will be required in each condition to produce a stable mean value to allow comparison. A minimum of 8 trials will be recorded for any one condition as a balance between achieving statistical power and requiring participants to perform too many scrums in total, as well as using values from previous force analysis research (James et al., 2007). Appropriate rest will be allowed between trials to negate fatigue effects.

For the second session, the forward packs will perform all experimental trials using normal engagement technique but on an alternative scrum machine and also the same scrum machine under different resistance settings. This will provide an indication of how machine set-up influences the measured variables recorded.

The research project is arranged into a number of work packages (WP), each with their own specific deliverables, and resourced by the most appropriate mix of the research team.

WP1: Measurement of impact forces during scrum engagement with instrumented scrummage machines (Kenchington, Trewartha)

The scrum machines will be instrumented, using Smart DDM technology, with multiple strain gauges bonded and calibrated to allow accurate measurement of the axial, vertical and lateral loads experienced at the impact interface between the front row and the scrum machine. Smart DDMs, or Distributed Data-Acquisition Modules provide a means by which the output from all of the sensors can be sampled synchronously, at high frequency. sDDMs are able, automatically and autonomously, to record data for a period commencing prior to the initial impact and finishing after the end of the
sustained shove. Preliminary calibration trials have been carried out on a scrum machine, these have indicated that it will be possible to obtain very high quality data. The monitoring system will be further enhanced to control several video cameras and to provide them with a common synchronisation signal (See WP2 below). Forces generated through each individual front row player will be measured and then summed to determine the combined initial impact forces and the sustained load. The data will be appropriately combined and filtered to permit determination of key values such as: peak axial, vertical and lateral forces during the impact; and the shove. Sensors will also be fitted so that both the displacement and rotation of the scrum machine are simultaneously monitored.

The primary outcome measure will be the peak impact forces generated by each forward pack. The data will indicate the capabilities of a wide range of forward packs (with respect to age, gender, mass and capability). The last is likely to show what has been achieved through the performance enhancement techniques introduced since earlier attempts were made to measure these forces (using less sophisticated equipment) (e.g. Milburn, 1990)

The intention of this study is to provide accurate, up-to-date information regarding the impact forces experienced by rugby forwards during scrum machine engagement. This information will provide baseline measures on forward packs sampled from different levels of the game and will also provide initial comparative data for a small number of alternative engagement techniques and scrum machine types.

**Duration:** 4 months equivalent

**Outcome:** An analysis of the impact force characteristics experienced by forward packs scrumming against a machine.

**WP2: Measurement of upper body segmental motions during scrum engagement with an instrumented scrummage machine (Trewartha, Stokes)**

Force data from the scrum machine will be time-synchronised with video data from multiple cameras. At least one high-speed video camera (minimum sampling rate = 200 Hz) will view the scrum engagement from ‘above’ (at least 6 m above ground level) with additional standard digital video cameras viewing the engagement from alternative viewpoints, e.g. from the ‘side’ and from ‘behind’. Synchronised video will be time-stamped with the corresponding force data and sequences will be visualised to allow qualitative understanding of the motions of the players and primary contact points during scrum engagement.

Selected trials for each forward pack will be subjected to additional quantitative data processing of the high-speed video footage to reconstruct the 2-D horizontal motions of the forward pack during scrum engagement. Video digitising of the movement sequences will be performed using Peak Motus 8.0 software following previous calibration of a plane of movement using points of known global location. A reduced body model will be created for each player in the pack, involving, for example, digitising of head, neck, shoulder and hip points. Reconstruction of these points will allow calculation of segment orientation angle changes during engagement (e.g. lateral neck flexion, lateral spinal flexion) and will also allow determination of momentum (velocity) changes occurring on each individual player within the pack during the engagement sequence. This type of video analysis is standard within the field of sport biomechanics research, is accepted by the research community, and has well defined error limits.

**Duration:** 4 months equivalent

**Outcome:** An analysis of the individual and collective motions experienced by rugby forwards during scrum engagement against a machine.
WP3: Linking to injury mechanisms and establishing the future research agenda for rugby scrummaging (Trewartha, Stokes, England, Kenchington, Steering & User Groups)

The results obtained from WP1 and WP2 will be compared to injury threshold data available from the wider published literature, taking into account the proposed injury mechanisms and the motion and force data observed in the experimental studies. This will provide an indication of the proximity to injury limits during normal scrummaging.

Through the establishment of a steering and user group it will be possible to generate an informed vision for the specific future research requirements relating to rugby scrummaging. WP3 will generate this future vision through conducting a comprehensive 'needs analysis', incorporating: exhaustive reviews of scientific and rugby coaching literature; received input from the steering group; communication with other leading authorities in scrummaging including players, coaches, referees and medical staff; and questionnaires and written communication with the user group. By using appropriate communication channels this WP will have a distinctly international flavour, eliciting input from as wide a catchment group as feasibly possible before making recommendations.

**Duration:** 2 month equivalent

**Outcome:** A game-wide, fully disseminated report including comparative data from machine scrummaging impact forces versus published injury threshold data and an agenda outlining specific future research directions to be taken with regards to performance and safety issues in rugby scrummaging.

WP4: Determining solutions for measurement of impact forces during live scrummaging and tackling (Trewartha, Almond, Bowen, Kenchington, Stokes)

Ultimately the goal must be to obtain data on the impact forces and body motions of rugby forwards during actual contested scrummaging. This is a non-trivial task but recent developments in technology and know-how mean that this problem is now tractable. During the experimental trials for WP1 and WP2, additional measurement instrumentation will be attached to a sub-set of the participant packs to determine which data can be used for analysing player-to-player contacts in live scrummaging and also tackling. WP4 will research and evaluate a number of possible solutions for obtaining such data ‘in the field’, focussing on pressure measurement and accelerometer/gyroscope technology, and will provide guidance as to possible technical solutions to be used in future research studies investigating live scrummaging (i.e. Phase 2) and eventually tackling.

**Duration:** 2 month equivalent

**Outcome:** Recommendations of potential solutions for the measurement of impact forces experienced during live scrummaging (Phase 2).

5.3 Originality, Timeliness & Novelty

This project proposal is timely since there is a lack of accurate, up-to-date information regarding the forces experienced by rugby forwards during scrummaging on scrum machines. Scrum machines are widely used as training tools at all levels of the game but little is known regarding the forces experienced by participants during their routine use. Previous research on the biomechanics of machine scrummaging was conducted nearly twenty years ago and considerable changes have been made in scrummaging technique and scrum training equipment since then as well as advances in the ability to measure the forces developed. The originality/novelty of this work lies in: (a) the methodologies used to obtain the data, and particularly the synchronous recording of impact forces with body motions;
(b) the inclusive nature of the project, where the intent is to analyse forward packs from a broad range of the rugby playing population and to receive the widest possible international consultation regarding the direction and monitoring of project progress, and to impart the fullest possible dissemination of the results.

5.4 Applications / Further Work
Phase 1 of this project will determine the biomechanical characteristics of machine scrummaging for forward packs in contemporary rugby union. Data will be acquired on forward packs representing different levels of the game, in terms of playing standard, age and gender. Values will be produced for currently applied laws and standard engagement techniques with comparative values from a small number of initial alternative conditions, including different scrum machine resistance settings.

A number of future avenues are possible, including (but certainly not limited to): the testing of other different engagement techniques, further development of scrum machine technology to improve safety and comfort for all participants, and a comparison of live scrummaging versus machine scrummaging. An important area for further work is to strive for the robust measurement of scrum impact forces and body motions during live contested scrummaging (Phase 2A).

5.5 Dissemination
The project team will aim for the widest possible dissemination of the project results. Dissemination of the project results will initially be through the Management Group and steering group onto the user group (defined in Section 8) as appropriate, but will ultimately exploit multiple outlets and formats, including: media exposure, the IRB web site and national governing bodies. The results of the research will also be submitted for publication in high-impact peer-reviewed scientific journals.
5.6 Biomechanics of the Rugby Scrum: Phase 1 Workplan

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*Final report to be submitted one month following completion*
5.7 Phase 1 – Justification of Resources

University of Bath

Staff: Support is requested for a full-time postdoctoral research assistant (RA) to be based at Bath for the duration of the project. Given the nature of the research and particularly the time-critical requirements of this project we feel it is important to appoint an established researcher who can “hit the ground running”. This RA’s main duties will be literature searching, data collection, video data processing, data analysis and communication with equipment manufacturers to arrange demonstrations of sensor technology for WP4. The University has agreed to reduce the overhead recovery rate for this post from 100% to 50%. Support is requested to cover direct salary costs for Grant Trewartha for the equivalent of 1 day per week for the duration of the project. Dr Trewartha will be involved in planning and execution of data collections, supervision of video data processing and analysis, and evaluation of technologies for WP4. Support is also requested for Keith Stokes at an equivalent of 0.5 day per week. Dr Stokes will be involved in planning of data collections for WP2 and will take a lead role in WP3 to generate the future research agenda. The University has agreed to cover the overhead costs for Trewartha and Stokes.

The scrum coach will be present at all testing sessions to standardise the procedures used and ensure that all participant packs perform the alternative engagement procedures appropriately.

A research technician is required at the equivalent of one day per week for the duration of the project to assist in various tasks including: construction of video calibration devices, electronic circuits for data synchronisation, data collection set-up and equipment maintenance.

Equipment: A pressure measurement system will be hired to measure the contact pressures across the contact interface between front-row and machine and to explore its potential for full utilisation in Phase 2 (live scrummaging). In a similar vein, a small number of accelerometer/gyroscope units will be purchased for trialling with full utilisation in Phase 2. The trialling of these technologies in Phase 1 is imperative since data can be evaluated against the criterion of the instrumented scrum machine to provide overall confidence in the technologies.

Consumables: A small amount of funding is requested to cover experimental consumables, including hire of a scaffold gantry or lifting platform for siting the video camera, for storage of video media and for participant expenses.

Meetings: Expenses are required to cover the travel costs and refreshments for members of the steering group and user group attending meetings.

Structural Statics Ltd
Support is requested to cover staff costs and consumable to cover the operation of the instrumented scrum machine for the main trials. Staff costs are requested to support the availability of two engineers during the main trials and consumable costs to cover the provision of the sensor technology to the project for the duration. A small amount of development time is also requested to permit software development to synchronise the force acquisition hardware (Structural Statics) with the video hardware (Bath). The management time (Alan Kenchington) and administration time is being provided at no charge.
6. PHASE 2: The Biomechanics of Live Scrummaging

Please Note: The objectives and content for Phase 2 of the programme of work will be informed by the findings of Phase 1. As such the objectives, methodology and budget breakdown (identified in Schedule 1 of the Research Agreement) are indicative and represent best predictions. It is also noted that the Initial Fee for the Project will not be increased.

6.1 Aims & Objectives
The aim of this project is to characterise the biomechanics of live scrummaging, in order to understand better the physical demands being experienced by rugby players during this phase of play and to investigate ways in which performance can be improved and injury potential may be managed.

The research objectives of this project (Phase 2, parts A and B inclusive) are to:

- Obtain calibrated contact pressure data across the interface between the front rows during live scrummaging
- Characterise the relative accelerations experienced by front row players during scrummaging, to include head and trunk linear accelerations and ‘neck’ angular accelerations
- Obtain standard and high-speed video footage of scrum engagements from multiple perspectives, synchronised to the pressure and acceleration data, to perform qualitative and quantitative analysis of player motions during the engagement sequence
- Associate pressure, acceleration and motion data with proposed injury mechanisms and available injury thresholds

6.2 Programme of Work (Indicative)
Experimental Design
This project will employ a group-based cross-sectional experimental design. Groups will be formed by recruiting forward packs from various playing categories, including youth, women, university, community club and professional levels. Where feasible, a number of forward packs will be recruited into each group (approximately 6 forward packs per group, see below for sample size calculations) to allow between-group comparisons to be made for the outcome measures. This sample size aim will be more difficult to achieve for elite playing levels.

Sample size calculations have been performed based on existing evidence from scrum machine data, assuming a factorial between-within design:

Basis of sample size calculation: To allow the identification of differences in impact forces due to playing level (between factor, 6 levels) and due to scrum engagement technique (within factor, 3 levels) a factorial between-within design is utilised. The sample size calculation has been performed (G*Power software, version 3.0) using the following criterion, with effect size estimated using the peak force data of Milburn & O’Shea (1994):

Mean sample 1 (standard engagement) = 5882 N;
Mean sample 2 (sequential engagement) = 4833 N;
Combined standard deviation (estimated) = 1000 N.

Therefore, estimated Effect size = (Mean₁ − Mean₂) / SD = (5882-4833)/1000 = 1.05
α error probability = 0.05
Power (1-β error probability) = 0.8
Number of Groups = 18 (e.g. 6 playing levels x 3 engagement techniques)
An a priori sample size calculation for an ANOVA with repeated measures and within-between interaction results in a total sample size = 36 with an actual power = 1.00.

Therefore, the required number of samples per condition (teams in any given playing level) = 6.

Experimental Procedures
All experimental trials will be performed in an outdoor environment on dry natural turf.

Two forward packs from the same playing category will attend a data collection session together on two occasions. Each pack will alternate between being the “tested” pack and “opposition” pack for one occasion each. Measurement instrumentation will be attached to players of the “tested” pack and analysis will focus on this pack. The two packs will participate in fully contested scrumming for the experimental trials, following instructions not to engage in techniques which contravene the Laws.

Participants will be attired in their own rugby boots, socks, shorts and short-sleeve tops or custom-made binding tops (designed to replicate normal binding opportunities on standard rugby tops but aid analysis). Following appropriate warm-up drills and coaching in alternate engagement conditions, each pack will scrummage against the “opposition” pack. A minimum of 24 (maximum of 30) engagements with sustained shove will be completed, with a minimum of 8 trials per engagement condition. It is expected the alternative conditions to be analysed will include ‘passive engagement’ and ‘touch-crouch-pause-engage’. A minimum of 8 trials will be recorded for any one condition as a balance between achieving statistical power and requiring participants to perform too many scrums in total, as well as using values from previous force analysis research (James et al., 2007). Appropriate rest will be allowed between trials to negate fatigue effects.

Data Collection
The measurement protocol for Phase 2 can only be finalised subsequent to Phase 1 analysis and so the following details are provided to be as accurate and comprehensive as possible within this context.

Total impact pressures and pressure distribution at the front row interface will be recorded at 100 Hz via a Tekscan pressure measurement system. Pressure sensors will be worn by the front row players of the “tested” pack, positioned over the superior aspect of the trunk from the base of the neck to the acromiom process and held in place through the use of customised shoulder pad vests. The pressure sensors will have been previously calibrated (static and dynamic methods) to allow conversion of the summed pressures to determination of impact forces on each shoulder of the front row players. These normal forces can then be summed to provide an indication of overall impact force. Additionally, regions of abnormally high pressure will be identified by referencing the position of the pressure sensor relative to shoulder girdle anatomy using methods similar to Trewartha & Stokes (2003).

Head and trunk accelerations will be determined via tri-axial accelerometer and gyroscope units securely attached to the skin surface on the spine and head of the tested front row players. High range accelerometer (e.g. ± 35g) units will allow determination of three-dimensional accelerations of body segments during engagement with the embedded rate gyros allowing resolution of these accelerations into meaningful directions. Positioning of units on the upper spine (e.g. C7) and near the
atlas will allow for determination of joint angular accelerations, e.g. neck flexion/extensions accelerations.

**Trunk and head motions** of each player involved in the scrum will be recovered via high-speed video in a manner identical to WP3 in Phase 1. The video camera will be positioned almost directly above the scrum and a plane of movement calibrated prior to the recording of trials. Following recording of the scrum engagement sequences under each experimental condition, videos will be digitised using Peak Motus software, employing an upper body model for determining points to be digitised. Where possible, superficial skin markers will be positioned on anatomical landmarks of the players to aid identification. Processing of the digitised movement data will permit the recovery of trunk and head motions including segment velocities pre- and post-contact, the magnitude and direction or resultant momentum for each player, lateral spinal flexion angles throughout the engagement and lateral neck flexion angles.

**Data Analysis**

Key biomechanical measures will be extracted as multiple dependent variables and tested for main or interaction effects due to playing level or scrum engagement technique. Key measures will include but not be limited to: magnitude of peak pressures, magnitude of peak trunk, head and neck accelerations, lateral spinal flexion range of motion.

**6.3 Originality, Timeliness & Novelty**

Phase 2 represents a new approach to characterise the biomechanics of live scrummaging. Research on live scrummaging has not been attempted before so it is potentially ground breaking in attempting this research. The technologies have been used in other fields of research (e.g. crash impact testing, animal locomotion) and so it is appropriate that these are now applied to rugby union research. The data collected will provide information on many variables known to contribute to injury mechanisms, such as magnitudes of pressure/force, loading rates and segment geometry. Producing information on the individual and combined forces and motion contribution to overall scrum motion will also provide worthwhile and novel information to coaches regarding which techniques can be employed to improve a scrum’s effectiveness.

**6.4 Applications / Further Work**

This project will determine the biomechanical characteristics of scrum engagement for forward packs in contemporary rugby union. Data will be acquired on forward packs representing many different levels of the game, in terms of playing standard, age and gender. Normative values will be produced for currently applied laws and standard engagement techniques with comparative values from a small number of initial alternative conditions. These data will provide objective evidence on which to base the direction and evaluation of future interventions designed to make scrummaging effective and safe. There are many potential opportunities for future research in this area. A small number of examples include:

- Association between individual anthropometric and strength variables with scrum impact characteristics
- Tracking of injury following any modified scrum engagement techniques
- Association of scrum impact biomechanics with mechanisms leading to degenerative conditions

**6.5 Dissemination**

Dissemination of the project results will initially be through the Project Management Group and steering group onto the user group (as appropriate) but will ultimately
exploit multiple outlets and formats, including: media exposure, the IRB web site and national governing bodies. The results of the research will also be submitted for publication in high-impact peer-reviewed scientific journals.

6.6 Phase 2 Timescale of Outputs (Indicative)
It is anticipated that to analyse approximately 36 teams using the methods outlined above the project would need to last 24 months from outset to completion, with final reporting one month following completion. The workplan would include some time for calibration trials, the majority of time being required for collection and analysis of main trials in different (international) locations, with management group and steering group meetings at carefully selected time points.

For funding purposes, Phase 2 is separated into two parts: Phase 2(A) and Phase 2(B), each of 12 months duration.

Outputs to be delivered from Phase 2(A) will be calibration trials followed by analysis of live scrummaging for a total of 6 forward packs.

Outputs to be delivered from Phase 2(B) will be analysis of live scrummaging for a further 30 forward packs approximately.

Changes to the scope of the Project:
UOB and the Company agree that following the outcome(s) of Phase 1 of the Project they shall consult to assess if the scope of the Project as outlined in this Agreement including Schedule 2 hereof continues to remain valid and/or appropriate in light of the findings. In circumstances where the Company and/or the parties collectively consider that adjustments need to be made to the scope of Phase 2(A) and/or Phase 2(B) of the Project they shall agree to an adjustment procedure and amend the Project Phase 2(A) and/or Phase 2(B) accordingly. For the sake of completeness any adjustments to Phase 2(A) of the Project shall necessarily fall within the parameters of the Initial Fee.

6.7 Phase 2 – Proposed Resources (Indicative)

University of Bath
Staff: One full-time postdoctoral research assistant (RA) to be based at Bath for the duration of the project. The RA’s main duties will be development of measurement protocols; programming of analysis software; subject recruitment/liaison; data collection, processing and analysis. Direct costs of project investigators time. The scrum coach will be present at all testing sessions to standardise the procedures used and ensure that all participant packs perform the alternative engagement procedures appropriately. Partial support for a research technician for the duration of the project to assist in various tasks including: development of electronic circuits for data synchronisation and transfer, data collection set-up and equipment maintenance.
Equipment: Purchase of a pressure measurement system, additional accelerometer and gyroscope units and wireless transceivers.
Consumables: To include hire of a scaffold gantry or lifting platform for siting the video camera, disk storage of video media, participant expenses.

Structural Statics Ltd
Staff: To support the availability of an engineer during the main trials and for software development time. Direct costs of project investigators time.
Consumables: To cover the provision of the sensor technology to the project for the duration.
7. RELEVANCE TO BENEFICIARIES

IRB (through its operating entity IRFB Services (Ireland) Limited – the “Company”) – The IRB will benefit directly from the project outcomes since it will provide detailed objective data regarding the impact forces and player movements experienced during the scrum engagement sequence. For the first time this information will have been collected on players representative of many different levels of the game, including youth, community and women’s rugby union. By establishing robust, normative data on scrum engagement forces, along with comparative data from alternative engagement conditions, the IRB will possess information on which it can inform future coaching, education and law changes.

Rugby players – Unfortunately, although very few in number, catastrophic injuries do occur due to rugby scrumming. In addition, the degenerative conditions which may arise from chronic exposure to scrumming represent a risk to player welfare in the long term. By producing the baseline data on scrum impact forces against which future interventions can be evaluated, rugby players from the entire rugby playing population will ultimately benefit in the long-term from this overall programme of work in the sense that law/coaching/equipment modifications to improve scrum safety and performance can be pursued based on clear evidence. Also, knowledge of optimum body positions and motions for effective scrumming will enhance performance.

Research community – The dissemination of the data from this project will offer opportunities for the research community to progress the understanding of performance enhancement and injury risk in rugby union. For example, knowledge of the body positions and motions leading to effective scrumming will provide a basis for the biomechanical testing of players to improve individual player techniques and training regimes. Also, experimentally-obtained scrum impact force time histories and body motions could be used as the basis for more advanced biomechanical models to investigate loads being experienced on specific anatomical structures, e.g. vertebrae.

Equipment manufacturers – Better knowledge of what forces are applied by forward packs from different levels of the game will prove to be invaluable information for rugby equipment manufacturers to improve the performance and safety features of their products. This information will improve the understanding of the required technical specifications for scrum machines and provide direction regarding the need for design specificity for different levels, age groups and genders.

Coaches – Characterising the biomechanical demands of different scrum engagement techniques will allow coaches to understand the importance of correct technique and the influence that new techniques have on both player safety and scrum performance and will therefore serve to reinforce their coaching points to players. Again, knowledge of optimum body positions and motions for scrumming leading to effective performance will enhance the coaching process.

Referees – Providing referees with quantitative, up-to-date information regarding the influence of technique on scrum engagement forces will serve to reinforce their application of the scrum laws.
8. PROJECT MANAGEMENT

Project Management Group (Policy Group)

- **Management Group (Policy Group) – Terms of Reference**
  - To be responsible for all policy decisions affecting the project scope
  - To monitor project progress against the work plan
  - To consider any amendments to the work plan
  - To make recommendations relating to reallocation of budget for sign-off by the Company

- **Management Group (Policy Group) – Participants**
  - Bill Beaumont IRB Vice Chairman - (Chair)
  - Steve Griffiths IRB Head of Technical Services Department
  - Mick Molloy – IRB Medical Officer
  - Mark Harrington – IRB Training & Medical Manager
  - Safety Consultant (Subject to agreement)
  - NZRU Employee (Subject to agreement)
  - Grant Trewatha (BU)
  - Keith Stokes (BU)
  - Mike England (BU and RFU)
  - Alan Kenchington (SS)

- **Management Group (Policy Group) – Process**
  - Monthly reports to be received from the Work Project Group – Gantt Chart indicating progress against work plan
  - 4 monthly meetings (face to face and/or conference calls)
  - Meeting minutes
  - Change request reports (forms) to be presented by Work Project Group

No decision of the Management Group shall alter the findings of the Work Project Group.

Steering Group

- **Steering Group – Terms of Reference**
  - To provide technical advice to the Project Management Group only;
    - To confirm engagement processes for phase one and two of the project
    - To consider outcomes from the project on an ongoing basis
    - To provide feedback on the recommended outcomes from the project

- **Steering Group – Participants**
  - Graham Mourie – Chairman of Rugby Committee
  - Bill Nolan – IRB
  - Richie Dixon
  - Mike Cron
  - Ken Quarrie
  - Scrum Coaches x 4
  - Front Row forward player from Players Association
  - Paddy O’Brien, IRB Referee Manager

- **Steering Group Process – Process**
Provided with protocols for comment
Potential of one meeting face to face (November)
Email/Extranet communications

No decision of the Steering Group shall alter the findings of the Work Project Group.

User Group

- **User Group – Terms of Reference**
  - To receive outcomes from the research on a regular basis and to contribute to the technical debate on the outcomes from the project and recommendations

- **User Group – Participants**
  - Nominated technical personnel from the 17 High Performance Unions

- **User Group – Process**
  - The introduction of a project extranet where outcomes and recommendations can be shared with the user group and where they can make comments.

Work Project Group

- **Work Project Group – Terms of Reference**
  - To deliver the Project Outcome Objectives
  - To deliver the project research objectives
  - To undertake research in accordance with the work plan
  - To produce monthly progress reports for the Project Management Group

- **Work Project Group - Participants**
  - BU and SS personnel as indicated within the contract and work plan

- **Work Project Group – Process**
  - In accordance with the Project Work Plan

Please see attached RASCI Model

Scrum Coaches

- IRB to resource scrum coaches that will be able to deliver
  - Consistent engagement process
  - The effective management of the various participants taking part in the trials with the assistance of the Work Project Group
RASCI Model for Biomechanics of the Rugby Scrum Project

<table>
<thead>
<tr>
<th>Activity</th>
<th>Responsible</th>
<th>Authority</th>
<th>Support</th>
<th>Consult</th>
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<tbody>
<tr>
<td>Budget Approval</td>
<td>IRB</td>
<td>IRB</td>
<td>Management Group (MG)</td>
<td>Work Project Group (WPG)</td>
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<td>MG</td>
<td>WPG</td>
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<td>WPG</td>
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<td>MG</td>
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<td>WPG</td>
<td>SG</td>
<td>UG</td>
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<td>Research Activity</td>
<td>WPG</td>
<td>MG</td>
<td>WPG Members</td>
<td>SG</td>
<td>UG</td>
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<td>Technical Protocols – Engagement Processes</td>
<td>WPG</td>
<td>MG</td>
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<td>UG</td>
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<td>Ongoing Research Outcomes</td>
<td>WPG</td>
<td>MG</td>
<td>WPG Members</td>
<td>SG &amp; UG</td>
<td>IRB Rugby Committee</td>
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<tr>
<td>Producing Research Recommendations for implementation</td>
<td>WPG</td>
<td>MG</td>
<td>WPG Members</td>
<td>SG &amp; UG</td>
<td>IRB Rugby Committee</td>
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<tr>
<td>Communicating Research Recommendations</td>
<td>MG</td>
<td>MG</td>
<td>WPG</td>
<td>IRB Communications – Journals etc</td>
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<td>Implementing Research Recommendations</td>
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9. ETHICS AND QUALITY ASSURANCE PLANS

All the work described in the current proposal conforms to the declaration of Helsinki and ethical approval will be obtained via the University of Bath School for Health Research Ethics Approval Panel prior to any testing of participants. The University of Bath has a clear Data Protection Policy. All staff and students of the University who are in any way involved with the processing of personal data must ensure that any processing of personal data by them complies fully with the “University Data Protection Rules” which include the following:

i) The Data Protection Act 1998
ii) The University Data Protection Policy
iii) Any additional procedures or guidelines relating to Data Protection matters which may be issued by the University from time to time.
10. REFERENCES


Nigg BM and Bobbert M. On the potential of various approaches in load analysis to reduce the frequency of sports injuries. *Journal of Biomechanics* 1990: 23 (Suppl. 1): 3-12


11. INVESTIGATOR DETAILS

<table>
<thead>
<tr>
<th>Address</th>
<th>Telephone</th>
<th>E-mail</th>
<th>Fax</th>
<th>Date of Birth</th>
<th>Nationality</th>
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<tr>
<td>Sport &amp; Exercise Science</td>
<td>+44 (0)1225 383055</td>
<td><a href="mailto:g.trewartha@bath.ac.uk">g.trewartha@bath.ac.uk</a></td>
<td>+44(0)1225 383275</td>
<td>25 December 1976</td>
<td>British</td>
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<td>School for Health, 6 West</td>
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<td>University of Bath</td>
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<td>United Kingdom</td>
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</table>

**Employment History**

- Sep 2001 – present: Lecturer in Sport & Exercise Biomechanics, School for Health, University of Bath
- Dec 2000 – Aug 2001: Research Assistant in Biomechanics, Loughborough University

**Education**

- 1994 - 1997 BSc (Hons) Physical Education & Sports Science (1st Class), Loughborough University

**Selected Publications**

<table>
<thead>
<tr>
<th>Funding Body &amp; Programme</th>
<th>Research Funding Title of Project</th>
<th>Dates</th>
<th>Amount</th>
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<tr>
<td>University of Bath</td>
<td>Radio-based tracking of team sport players (Co-I)</td>
<td>Feb 2005- Jul 2005</td>
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<td>Enterprise Fund</td>
<td>Technical characteristics of successful evasive running manoeuvres in rugby union (PI)</td>
<td>Jul 2005- Aug 2005</td>
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<td>Nuffield Foundation</td>
<td>The control of rotation during rugby goal kicking (PI)</td>
<td>Apr 2005</td>
<td>£852</td>
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<td>Royal Society</td>
<td>Efficacy of hydroactive in maintaining hydration status during exercise (Co-I)</td>
<td>Jul 2005- Jun 2008</td>
<td>£76,536</td>
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<tr>
<td>GlaxoSmithKline</td>
<td>An Epidemiological Study of Injuries within English Community and Academy Youth Rugby Union (PI)</td>
<td>Mar 2006- Feb 2009</td>
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<td>Rugby Football Union</td>
<td>Assistive Rehabilitation Technologies for Patient Use (PI)</td>
<td>Jan 2007- Dec 2007</td>
<td>£33,262</td>
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</table>

**Research-Related**

**Visiting Appointments:** Visiting Academic Fellow, Biomechanics Research Laboratory, University of Wollongong (June – August 2006)

**Postdoctoral Research Supervision:** Dr Tom Stone (funded by RNHRD), Assistive Rehabilitation Technologies (Jan 2007-Dec 2007). Dr Paulien Roos, Biomechanics of trips and falls (May 2007 – April 2008).

**Research Student Supervision:** Completed: Paulien Roos, PhD (July 2007), “Contributions to successful trip-recovery in younger and older adults” Completed: Simon Roberts, PhD (October 2008), “Physical demands of elite rugby union and nutritional interventions” Lead supervisor for 1 full-time PhD student (funded by RFU) and co-supervisor for 3 full-time students

**Professional Memberships:** Member, International Society of Biomechanics Member, International Society of Biomechanics in Sport Member, British Association of Sport and Exercise Sciences

**Collaborations:** Prof Julie Steele (University of Wollongong, Australia) Dr Bridget Munro (University of Wollongong, Australia) Prof Fred Yeadon (Loughborough University) Prof David Kerwin (UWIC) Dr Cassie Wilson (UWIC)

**Reviewer:** Journal of Sport Sciences, Neuroscience Letters, Journal of Aging and Physical Activity, Sports Biomechanics, Sports Engineering & Technology

**Awards:** NAC/Miyashita Film / VTR Award for paper presented at International Society of Biomechanics XVIIIth Congress, July 2001, Zurich.
Keith Stokes, BSc PhD

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University of Bath
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BA2 7AY
United Kingdom

Telephone
+44(0)1225 384190

E-mail
k.stokes@bath.ac.uk

Fax
+44(0)1225 383275

Date of Birth
28 February 1975

Nationality
British

Education

1996 – 2001 PhD Management, Department of PE, Sports Science & Recreation
Loughborough University

1993 – 1996 BSc(Hons) Science, 1st Class in Geography & Physical Education & Sports
Loughborough University

Employment History

2002 – : Lecturer in Human and Exercise Physiology in the Sport and Exercise Science Group of the School for Health, University of Bath.

2001 – 2002: Lecturer in Exercise Physiology in the Department of Sports Studies, University of Stirling.

Research Interests

Improving performance and safeguarding player wellbeing during rugby

Hormone responses to exercise and physical activity

Recent publications


### Research Funding

<table>
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<tr>
<th>Funding Body</th>
<th>Title of Project</th>
<th>Dates</th>
<th>Amount</th>
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<tr>
<td>Rugby Football Union</td>
<td>Injury surveillance in English rugby union (PI)</td>
<td>Mar 2008-Jul 2012</td>
<td>£229,394</td>
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<td>Ministry of Defence</td>
<td>Influence of smoking on performance, physiological status and injury risk during initial training (PI)</td>
<td>Oct 2007-Sep 2010</td>
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<tr>
<td>Rugby Football Union</td>
<td>An epidemiological study of injuries within English community and academy youth rugby union (Co-I)</td>
<td>Mar 2006-Feb 2009</td>
<td>£64,795</td>
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<td>British Heart Foundation</td>
<td>Inflammation in Cardiovascular Disease (Co-I)</td>
<td>Mar 2006-Mar 2008</td>
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<td>GlaxoSmithKline</td>
<td>Assessing the efficacy of hydroactive (PI)</td>
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<td>Wellcome Trust</td>
<td>Effects of strenuous exercise on insulin-like growth factor-I (IGF-I) and IGF-I bioavailability (PI)</td>
<td>Jun 2004-Aug 2004</td>
<td>£1,280</td>
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<tr>
<td>Wellcome Trust</td>
<td>Physiological responses to cycling exercise with and without superimposed vibration (PI)</td>
<td>Jun 2003-Aug 2003</td>
<td>£1,240</td>
</tr>
</tbody>
</table>
Dr Mike England
MBBS MFOM MSc (SEM)

COMMUNITY RUGBY MEDICAL OFFICER, RUGBY FOOTBALL UNION.
Mike joined the RFU in 2005 and is tasked with delivering a world class Community Sports Medicine programme for the Community Game including:

- Research in relation to injury prevention
- Emergency first aid training for the community game
- Policy relating to player welfare
- Health and welfare guidance and support programmes
- Support for seriously injured players, their families and clubs
- Management of the England community squad medics

QUALIFICATIONS

- MSc in Sports and Exercise Medicine, University of Bath. 2002
- Certificate of Completion of Specialist Training (CSST) in Occupational Medicine. 2001
- Membership of the Faculty of Occupational Medicine (MFOM), Royal College of Physicians. 2000
- Membership of the Royal College of General Practitioners (MRCGP). 1995
- Joint Committee for Training in General Practice (JCTGP). 1995
- Bachelor of Medicine, Bachelor of Surgery (MBBS). 1998

KEY EXPERIENCES AND ACHIEVEMENTS (SPORTS MEDICINE)

- University College London Institute of Human Health and Performance, Project Board Member - Sports and Exercise Medicine Advisor
- Member of Faculty, tutor, research supervisor and examiner for Bath University Diploma/MSC in sports and exercise medicine
- Clinical team leader of trackside sports medicine support at Commonwealth Games 2002
- Managing acute and long-term rehabilitation of complex sports and trauma injuries, including post-operative patients as Medical Director UK Special Forces
- Experience of managing elite disabled athletes as physician to England cerebral palsy and blind football squads
- Highly experienced in preparing and travelling with teams and athletes
- Extensive experience in managing athletes at all levels, from amateur to professional elite, from child to adult from able bodied to disabled, in a range of sports
MEMBERSHIP OF PROFESSIONAL BODIES

- Royal College of Physicians, Faculty of Occupational Medicine
- United Kingdom Association of Doctors in Sport (UKADIS)
- Society of Occupational Medicine
- British Medical Acupuncture Society
- British Medical Association

RECENT CAREER HISTORY

2002-05    Regional Clinical Advisor and Consultant in Occupational/Musculoskeletal Medicine (MOD Army)
2002        Senior Management Training, Joint Services Command College
2000-02     MSc in Sports & Exercise Medicine, University of Bath
1997-00     Medical Director, UK Special Forces
1996-97     SpR Occupational Medicine, Directorate of Army Recruiting
1995-96     Senior Medical Officer (GP Non-Principle & SpR Occupational Medicine), Aldershot

EDUCATION

2003-04     Society of Orthopaedic Medicine Diploma Course (Cyriax)
2002        Advanced Command and Staff Course, Joint Services Staff College
2001-02     Master of Science, Sports and Exercise Medicine, University of Bath
2001        Foundation Training in Acupuncture and Membership of the British Association of Medical Acupuncture
2000        Approved Consultant in Occupational Medicine, Consultant Approvals Board, Royal College of Physicians
2000        Awarded CCST Occupational Medicine
2000        Membership of the Faculty of Occupational Medicine (MFOM)
1997        Associate of the Faculty of Occupational Medicine (AFOM)
1996        Certificate in Occupational Health, University of Aberdeen
1996-2000   Higher Professional Training in Occupational Medicine
1995        Membership of the Royal College of General Practitioners (MRCGP)
1995        Award of JCTGP
1995        Junior Command and Staff Course, Royal Military College, Sandhurst.
1992-95     General Practice vocational training.
1990        Post Graduate Medical Officers Course, Royal Army Medical College.
Alan Kenchington
Structural Statics Ltd
Burntwood
Kings Worthy
Hampshire
SO21 1AD

T: +44/0 1962 886644
F: +44/0 1962 886788
M: +44/0 7768 041513
E: alan.kenchington@structuralstatics.co.uk

UK citizen, D.O.B.: 1954, married, 2 sons

PROFILE

Alan Kenchington is a multi-faceted business person possessed of very highly developed technical skills. Throughout his working life he has worked in the general arena of innovation and invention, latterly focusing (but not exclusively) on advanced structural monitoring.

He has been responsible for taking Structural Statics from a ‘start-up’ occupying a shoe box in a borrowed office to being a highly respected ‘one-stop shop’ for innovative solutions for complex monitoring problems.

WORK HISTORY

1994 - Present  Managing Director, Structural Statics Ltd
(following a management buy-out)
1987 - 1994  Marketing Director, Structural Statics Ltd
1983 - 1987  Business Development Consultant, Structural Statics Ltd
1981 - 1989  Principal, AMK Associates, Innovation Consultants
One commission from London Docklands Development Corporation involved using advanced structural monitoring techniques to demonstrate potential for use of high level foundations within London Docklands. This led directly to his subsequent involvement in Structural Statics
1979 - 1981  Director, The Helicat Co Ltd
Private venture development and marketing of a small helicopter operating warship (with Rolls Royce, Vosper Thornycroft and BAe)
1977 - 1979  Various business ventures, including skateboard design and manufacture and skatepark consultancy for a number of local authorities!
EDUCATION

University of Bristol
Marlborough College
St Martin’s Preparatory School

SKILLS

In the course of his working life, Alan Kenchington has been directly involved in every aspect of running a number of businesses. He has been both responsible and accountable for individual and multiple concurrent projects ranging in value from a few thousands of pounds to multiple millions.

At the same time he has had direct involvement in all of the technical aspects of the work undertaken by the businesses and projects that he has been associated with. This has included but, is not limited to, analysis of functional and performance requirements; hardware and software specification; software development; electronic, electrical, mechanical and structural design; procurement, manufacturing, assembly & test, installation, commissioning, and validation, including all necessary preparatory works and documentation and the operation and maintenance of sophisticated and novel hardware and software; data-acquisition, processing, assimilation and interpretation.

Through Structural Statics, Alan Kenchington has played a significant role in a number of significant government and industry funded research and development projects. These have included multi-million pound projects carried out (with others including Devonport Royal Dockyard Ltd, DERA/Qinetiq and London Underground) for the DTI, DETR and multi-national petrochemical companies and major industrial concerns.

A very wide range of experience combined with a proven capacity to innovate, enables Alan Kenchington , through Structural Statics, to produce and implement solutions to problems that are at once ‘cutting edge’ and well suited to the ‘real world’.

Alan Kenchington has been associated with Structural Statics since its inception in 1983. He has been responsible for a large proportion of the company’s many innovations. In 2003, Structural Statics won the Queen’s Award for Enterprise in the Innovation Category which was won on the basis of lifetime as well as recent innovations and inventions.