An evidence-based injury prevention warm-up in grappling sports

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Contents

Abstract

Grappling sports, such as freestyle, catch, and greco-roman wrestling, have featured in the Olympic Games for over 100 years. However, no published injury-prevention warm-up (IPW) has been shown to lower injury incident rates within the three sports. Other grappling sports, such as Brazilian jiu-jitsu (BJJ), sambo, and traditional jiu-jitsu, also currently have no established IPW available. The aim of this review is to appraise the injury prevention practices and injury trends in grappling sports and use the findings to design an IPW that could be implemented across grappling sports. The Team-Sport Injury Prevention (TIP) cycle was used as a guideline to establish epidemiology, aetiology, and risk factors within each grappling sport. We found that the knee is the most injured site in freestyle wrestling, BJJ, sambo and traditional jiu-jitsu and the leading time loss injury in judo. Ligament strains were reported as the leading injury type in freestyle wrestling, BJJ and judo and second in traditional jiu-jitsu. In greco-roman wrestling and Judo competitions, the grappling sports that do not allow leg attacks, such as the head, neck, and trunk, are the leading injury sites. Assessing the barriers and facilitators of previous IPW, a deficiency of coach knowledge, lack of time, costs, scheduling, and equipment are the main obstacles to coach and athlete compliance. A knowledge group consisting of the authorship team, external medical practitioners, and coaches used the results of the TIP cycle to design an evidence-based IPW. Exercises with research confirming their effectiveness in lowering knee, shoulder and head injuries were selected. Where possible, the exercises selected were currently used in grappling warm-ups or strength and conditioning programmes. Future intervention studies are now needed to evaluate the efficacy of the IPW amongst grappling athletes.

Keywords

Grappling, Injury prevention, warm up, Wrestling, Brazilian jiu jitsu

Introduction

Grappling sports have been featured in the Olympic games since they started in 1896, beginning with greco-roman wrestling. Catch wrestling was introduced in 1904 before being replaced by freestyle wrestling in 1924, and judo was finally included in 1964. Evidence suggests that inadequate warm-ups are a common cause of injury in grappling sports (Blach et al., 2022) yet no published injury-prevention warm-up (IPW) has successfully lowered injury incident rates (Jäggi et al., 2015). Additionally, there is currently no IPW for other grappling sports, such as Brazilian jiu-jitsu (BJJ) and sambo. Overall injury incident rates (IR) for grappling sports have been estimated to be up to 19.6 per 1000 hours of athlete exposure (AE) (Powell et al., 2021), with competition rates reaching 109 injuries/1000 hours of AE (Pierantozzi & Muroni, 2009). Injury recurrence rates in grappling sports are high and estimated to be between 33% to 88% (Juliano Eustaquio et al., 2021; Sarro et al., 2022), with the most common site of reinjury, the knee, showing recurrence rates of 55% (Nakazawa et al., 2020). Research across different sports has shown that warm-ups prior to activity can reduce injury recurrence by up to 75% (Barengo et al., 2014; Coppack et al., 2011; LaBella et al., 2011).

Grappling is a key aspect of mixed martial arts (MMA). As MMA is taught as a distinct sport, it is common for coaches and researchers to refer to 'MMA grappling' when distinguishing from specific types of grappling, e.g., wrestling or judo (Fares et al., 2023; Thomas & Thomas, 2018). Given that different types of grappling exist, it is necessary to consider whether an IPW should be developed for specific types of grappling or whether a generic IPW could be transferable across specific grappling disciplines.

Injury prevention strategies have been proposed for judo and wrestling (von Gerhardt et al., 2023), although it is uncertain whether injury prevention strategies are transferable between grappling sports. The different rulesets and dress codes between each grappling sport make similarities between injury sites and mechanisms of injury (MOI) uncertain. grappling sports such as BJJ, freestyle, and catch wrestling allow contact with the hands to the head, trunk, and legs, whereas greco-roman allows contact only to the trunk and head and Judo only to the trunk. Judo, traditional jiu-jitsu, sambo and some forms of BJJ all wear a gi (a lightweight 2-piece outfit), with many of the throws and submissions involving the use of the gi. No-gi BJJ, greco-roman, freestyle and catch wrestling do not wear a gi. MMA grappling is also performed without a gi with many throws from judo and sambo being adapted to use head and hand grips rather than the gi. Additionally, the impact of submissions on injury site and MOI is not known for freestyle and greco-roman wrestling because these disciplines do not allow submission holds such as chokes and joint locks, unlike BJJ, sambo, catch wrestling and judo. Other well established IPW's within sport include the FIFA 11+, which was designed to reduce injuries in footballers (Bizzini & Dvorak, 2015). However, research has shown that it can successfully lower IR and biomechanical precursors to injury in basketball, netball and volleyball (Belcher et al., 2021; Hosseini et al., 2019; Longo et al., 2012), suggesting that IPW's can be effective if successfully integrated. Epidemiology studies have shown similar injury trends, with football, basketball, volleyball and netball reporting the ankle, followed by the knee, as the most frequently injured regions (Drakos et al., 2010; Gurau et al., 2023; Partner et al., 2018). Reviewing the available literature to understand the common types and sites of injury in grappling sports will help to establish if the injury trends between grappling sports are too broad for a single IPW. The review of injury data will also aid in the design of the IPW, allowing for the selection of evidence-based exercises that target frequently injured joints.

The aim of this review is twofold: (1) to appraise the current injury prevention practices and injury trends in grappling sports and (2) to design and propose an evidence-based IPW that could be used across grappling sports.

Section 1: Current recommendations to reduce injury.

There is a paucity of research into IPWs in grappling sports. von Gerhardt et al. (2023) evaluated the effectiveness of an IPW made up of judo specific exercises, named the Injury Prevention and Performance Optimization Netherlands (IPPON), and found that it did not reduce IR or the severity of injuries. To our knowledge, this is the only evaluation of a grappling-based IPW with IR data. Malliaropoulos et al. (2014) proposed an injury prevention programme for judokas that involved nine exercises that were a mixture of judo-specific movements (e.g., O-soto-gari and O-uchi-gari) and functional movements (e.g., forward jumps and lunges). However, to date, this injury prevention programme has yet to be used in any intervention studies, so its effectiveness is currently unknown.

There are several research studies that test variables that have been associated with injury risk. A sample of judokas were used to test the impact dynamic and static stretching warm-ups have on strength, power, acceleration, and flexibility (Eken et al., 2020). The results recorded a 9.9% increase in flexibility performance with no changes in strength, power, or acceleration (Eken et al., 2020). In contrast, Polat et al. (2018) found that a ballistic stretching warm-up increased isokinetic strength and flexibility in a sample of freestyle wrestlers.

In Iranian adolescent freestyle wrestling, a 12-week warm-up improved certain aspects of the functional movement screen (FMS), such as the deep squat, hurdle step, in-line lunge and trunk stability tests (Bayati et al., 2019). However, significant differences were not present for shoulder mobility, active straight-leg raise and rotary stability (Bayati et al., 2019). Furthermore, multiple studies have demonstrated that the FMS is not associated with injury occurrence and, therefore, does not have predictive validity (Dorrel et al., 2018; Hoover et al., 2020; Philp et al., 2018). Additionally, some studies establish the effect of warm-ups on performance in judo. Elkin et al. (2019) evaluated a dynamic warm-up in the raise, activate, mobilise, and potentiate (RAMP) format and found increased performance for the specific judo fitness test (SJFT) in female judokas (Eken et al., 2022). A study by Lum (2019) used upper and lower body post-activation potentiation (PAP) exercises in a warm-up format for a sample of male judokas. It demonstrated improvements in the number of throws judokas could perform in the SJFT (Lum, 2019).

There is no research investigating IPW in BJJ, sambo, greco-roman or catch wrestling. However, there is research that may inform the development of IPW. Grindstaff and Potach (2006) reviewed wrestling injuries and suggested exercises that could be incorporated into a strength and conditioning (S&C) programme. This resource is helpful for S&C coaches and provides a framework for a gym-based injury prevention programme. However, many of the exercise suggestions involved gym equipment that would not be feasible to integrate into a team warm-up. However, some bodyweight exercises, such as wheelbarrow holds and bear crawls, may be adapted to fill a warm-up format.

The use of IPW have successfully reduced injury rates and precursors to injury in sports such as football, basketball and rugby (Attwood et al., 2018; Bizzini & Dvorak, 2015; Gianotti et al., 2009; Riva et al., 2016). Following a similar systematic evidence-based approach as these programs should allow for an effective injury prevention warm-up protocol for grappling sports to be designed.

Section 2: Overview of the nature of injuries in grappling sports

Anatomical site of injuries and Type

Multiple studies have found the knee to be the most frequently injured anatomical site in BJJ, with estimates between 20.8 to 81.1% of all injuries (Barreto et al., 2017; Hinz et al., 2021; Kreiswirth et al., 2014; Lopes et al., 2021; Nery et al., 2022; Scoggin et al., 2014; Silva Junior et al., 2018; Usuki et al., 2017). Two studies found hands and fingers to be the most frequent injuries in BJJ, followed by the knee (De Almeida & De Araújo, 2020; Hunker et al., 2023; McDonald et al., 2017). An injury surveillance study by Scoggin et al. (2014) found that BJJ athletes reported the elbow (38.9%) to be the most commonly injured joint, although the knee had the highest incidence of medical diagnoses (19.4%); it was not known whether injuries came from gi-based BJJ or No-gi BJJ. Stephenson & Rossheim (2018) found that the head, neck and trunk were the leading injury sites of BJJ athletes presenting to American emergency departments between 2008 and 2015 (Stephenson & Rossheim, 2018). Evidence suggests that sprains are the most common injury type for BJJ injuries and are reported to be between 22.1% and 64.2% of all injuries (Barreto et al., 2017; De Almeida & De Araújo, 2020; Juliano Eustaquio et al., 2021).

In several American collegiate wrestling injury surveillance studies, the knee has been reported as the most frequent injury in competition and practice (16.7% to 30.4%) (Agel et al., 2007; Jarrett et al., 1998; Kroshus et al., 2018; Powell et al., 2021; Yard et al., 2008). However, this differs in American high school wrestlers, where the head/face (practices = 19.9%, competitions = 21.4%) and shoulder/clavicle (practices = 14.1%, competitions = 21.0%) were the most common injury sites (Kroshus et al., 2018). In international Olympic-style wrestling competitions, such as the world and European championships, the head and face were reported as the leading injured sites, with 29.1%, followed by the spine and trunk at 16.4% (Molnár et al., 2022), with the highest prevalence of head and face injuries being reported (71.4%) at the 2020 Tokyo Olympic games (Shadgan et al., 2021). Several studies have reported strains/sprains to the knee as the most frequent injury type among wrestlers (Agarwal & Mann, 2016; Barroso et al., 2011; Yard et al., 2008).

There is no IR data for catch wrestling and only limited data for sambo and traditional jiu-jitsu. Lapaeva and Tabakov (2021) used a mixed sample of sambo and judo athletes and established that the knee joint was most commonly injured (38.3%). In traditional Jiu-jitsu, the knee (29.4%) is reported as the most frequent injury site (Sistar et al., 2023). Minor contusions, sprains, and muscle injuries (54%) have been reported to be the most common injury type (Nicolini et al., 2021).

There is inconsistency in the most frequent injury site found in studies investigating greco-roman grappling, i.e., the neck (Daneshmandi et al., 2020), ribs (Akhmedov et al., 2016) and shoulder (Sandeep & Kuloor, 2017). In competition, lacerations to the face are the leading injury site and type (62%) (Akbarnejad & Sayyah, 2012). Mooren et al. (2023) conducted a systematic review of injuries during judo tournaments. The study concluded that the majority of included studies found the head and neck to be the commonest site of injury, the knee the commonest site of injury resulting in time loss, and the joint sprains, contusions and lacerations the commonest type of injury. Akoto et al. (2017) found that anterior cruciate ligament (ACL) ruptures were the primary injury type for time loss in judo, with 32% of all ACL injuries taking 6-9 months for grapplers to return to play (Akoto et al., 2017).

Risk Factors

There is currently a paucity of large-scale research highlighting the risk factors associated with grappling sports. However, several single studies provide some initial insights on modifiable factors that could be considered when designing an injury prevention programme. In youth freestyle wrestling, a relationship has been found between reduced flexibility and an increased rate of skeletal and muscular-tendinous injuries (K=7.89; P=0.04) (Nokhodchi & Moavenafshari, 2013). A link

between increased bone injuries and grapplers with low isometric strength was also established (K=7.92; P=0.04) (Nokhodchi & Moavenafshari, 2013). Sarro et al. (2022) season long study of injury profiles in BJJ athletes showed a decrease in peak torque (effect size between 0.04 and 0.09) and a small increase in the magnitude of interlimb asymmetry (effect size between -0.30 and -0.28) were observed post season in the knee and shoulder, with imbalances also seen in interlimb strength. The authors linked these variables with increased injury rates seen throughout the season. In judo, grapplers that have suffered previous back injuries have been shown to have a reduction in active and passive total hip rotation (82.6 ± 7.6°vs 87.6 ± 9.8°; P = 0.04) when compared to grapplers with no previous injuries to the back (Almeida et al., 2012; Sarro et al., 2022). Lockhart et al. (2022) systematic review showed that in judo, there is considerable research into breakfall techniques. Previously, poor collision biomechanics have been shown to be associated with head and neck injuries among grappling athletes (Lockhart et al., 2022). Practising correct falling techniques has been shown to lower these dysfunctions (Lockhart et al., 2022). When questioned, sambo athletes believed that ligaments or muscle weakness (26%) and a poor warm-up (15%) were key factors in their previous injuries (Lapaeva & Tabakov, 2021).

Although research into risk factors is lacking in grappling sports, the available studies suggest that strength, power, and flexibility affect injury incident and prevalence rates. The decline in these physical attributes seen with age may be the reason that injury incident rates increase with age (Trombetti et al., 2016; Wiegmann et al., 2021). An exercise selection with evidence of increasing strength, power and flexibility will be included in the IPW.

Mechanism of Injury (MOI)

Freestyle wrestling research is unanimous in stating that takedowns were the leading MOI, resulting in 39% to 54.3% of all reported injuries (Agel et al., 2007; Bell, 2023; Boden et al., 2002; Jarrett et al., 1998; Kroshus et al., 2018; Yard et al., 2008). The majority of these occurred during practice sparring, 37.5% to 65,1% (Agel et al., 2007; Bell, 2023; Jarrett et al., 1998; Yard et al., 2008). This was also seen in BJJ, where studies reported that 74 to 77.6% of injuries happened during training (Barreto et al., 2017; Hinz et al., 2021). It was also established that submissions (29.7%) were the leading MOI, followed by takedowns (26.4%). An opponent attempting an armbar was the leading submission to cause injury, and the triangle submission was the leading cause of injury for grapplers attempting a submission on their opponent (Hinz et al., 2021). The MOI has also been shown to differ between ages, with one study reporting the leading MOI for adolescents as tumbling/ trauma and takedowns as the lead MOI for adults and masters (Das Graças et al., 2017). In BJJ competitions, the armbar was the most common MOI (28.8%), followed by takedowns (13.9%) (Scoggin et al., 2014).

Sandeep and Kuloor (2017) study of greco-roman wrestlers found that most injuries accrued with contact with the opponent. However, further details of the contact or why it occurred were unavailable. However, Yard and Comstock (2008) further clarified contact details by stating that 54% of injuries in greco-roman wrestling came from being driven into the mat. A systematic review of competition injuries in Judo found that 50 to 85.2% of injuries happened during tachi-waza (Standing techniques) (Mooren et al., 2023). The most frequent method of MOI in standing techniques is being thrown, followed by performing a throw and then grip fighting (Green et al., 2007; Maciejewski & Pietkiewicz, 2016; Miarka et al., 2018). The available research shows that takedowns and throws are the leading aetiology in all styles of wrestling and Judo, with BJJ research fluctuating between takedowns and submissions.

Upper body injury

One of the leading MOIs in BJJ is the armbar (Hinz et al., 2021; Scoggin et al., 2014). The armbar is a submission that involves grapplers hyperextending their opponent's elbow joint by inflicting a posterior to anterior (P/A) force to the humerus and an anterior to posterior (A/P) force to the forearm (Almeida et al., 2017; Cond, 2018). Almeida et al. (2017) studied patterns and mechanisms of armbar injuries and stated that force caused by the eccentric contraction of the forearm flexor muscles leads to injury of the dynamic and static medial stabilisers of the elbow. The chances of dislocation and distal humerus shear fractures expand as the valgus moment increases when the elbow is at full extension (Giannicola et al., 2010; Schreiber et al., 2013). Due to the level of force that can be produced, it is unlikely that the IPW will have any impact on reducing injuries from armbars; instead, the focus should be placed on coaches to ensure there is correct sparring etiquette and a logical pairing of sparring partners with similar weight and experience levels.

The head and neck are leading injury sites in judo and greco-roman wrestling, with the direct impact of the head or shoulder on the mat being stated as a frequent MOI (34.9%) (Daneshmandi et al., 2020; Lockhart et al., 2022), resulting in 60% of all acute subdural haematomas reported in judo. Research into the causes of head injury in judo has shown that grapplers landing from unexpected throws (eyes closed) exhibited greater maximum angular acceleration of the head compared to expected throws (eyes open) (Hayashi et al., 2022). The delayed reaction to a push and delayed contraction of the neck muscles has also been linked to the increased risk of head injury (Hayashi et al., 2022). It was also seen that anterior cervical flexion strength did not impact angular acceleration (Hayashi et al., 2022). Research on the Ukemi breakfall techniques has shown that they can dramatically reduce peak resultant translational acceleration (PRTA) of the head that is associated with acute subdural haematoma and coronal rotation linked to diffuse axonal injury (Ishikawa et al., 2018; Koshida et al., 2014; Murayama et al., 2020). The backwards breakfall (Ushiro Ukemi) is a technique that uses the hand, forearm and trunk to attenuate impact forces from the head by reducing vertical velocity (Hashimoto et al., 2015). It imitates the falling pattern of an A/P takedown or a backward fall, making it relevant to all grappling sports. Lockhart et al. (2022) systematic review of breakfall biomechanics suggests training fall timing patterns and dynamic strength improve breakfall technique. Both aspects will need to be addressed in the IPW.

Research evaluating injury reduction strategies in rugby union and MMA has shown neck strengthening exercises should be used to reduce both the number and severity of cervical muscle injuries and sports-based concussions (Garrett et al., 2023; Liu, 2022). Neck strength has been associated with peak angular momentum of neck extension (PAMNE) (Lockhart et al., 2022). PAMNE has been shown to be lower in experienced judoka when compared to novices when performing break falls (Koshida et al., 2017). As neck strength was not tested in the study, it is unclear if PAMNE was lower due to better breakfall technique or from neck strength. Including breakfall drills and neck strengthening exercises in the IPW appears necessary.

Lower body injury

Takedowns have been verified as the most utilised method for scoring points in competitions and are practised regularly in grappling sparring and drilling (Cipriano, 1993; Fujiyama et al., 2019; Tünnemann & Curby, 2016). It has been established that many BJJ, freestyle, and catch wrestling takedowns and most noticeable leg attacks involve knee torsion, lateral knee displacement, and excessive force transmitted in the joint in the execution phase (Levitsky et al., 2017; Sacripanti, 1988; Yamashita et al., 2020). Research into anterior cruciate ligament (ACL) injuries states that the primary kinetic mechanisms are valgus forces, compressive anterior force of the quadriceps and short axial compressive forces to the knee that cause anterior translation of the tibia (Boden et al., 2002). These variables contribute to the most frequent component of ACL injury, a proximal tibia anterior shear motion(Bennett et al., 2008; Sell et al., 2007). The medial collateral ligament (MCL) is

commonly injured through coronal plane impact merged with rotational forces (Laprade & Wijdicks, 2012; Phisitkul et al., 2006). The kinetic forces seen in pivoting movement, rapid deceleration, and forced hyperextension are chief mechanisms in combined knee ligament injuries (Elkin et al., 2019).

It is apparent that these MOIs align with the mechanisms of leg-based takedowns frequently performed in BJJ and various types of wrestling. Additionally, it has been observed that freestyle wrestlers rely predominantly on leg attacks and not throws, as seen in greco-roman wrestling and judo (Cipriano, 1993; Pasque & Hewett, 2000). This is due to rulesets, as it is not permitted to grab the legs in greco-roman wrestling and judo. This has led to different defence strategies and postures between grappling styles that can attack the legs and those that cannot. Grappling styles that permit leg attacks, such as BJJ, freestyle and catch wrestling, demonstrate greater A/P excursion of the centre of pressure and greater knee flexion angles. This results in significantly increased joint angles in the transverse and frontal planes at the knee and ankle due to the lowered stance needed to attack and defend the lower limbs (Jang et al., 2009; Miarka et al., 2018). In turn, this may contribute to the higher percentage of knee and lower limb injuries and higher injury prevalence rates seen in freestyle wrestling (Akbarnejad & Sayyah, 2012; Daneshmandi et al., 2020; Yard & Comstock, 2008). As suplexes are not permitted in BJJ, it can be presumed that the majority of takedowns are attacks to the legs and not throws, as seen in greco-roman wrestling and judo (Akhmedov et al., 2016; Mooren et al., 2023). This leads to the conclusion that grappling sports that allow leg attacks share similar MOI to those not permitted to perform leg attacks. Unlike technique drilling for head injuries and coaching advisement for submission injuries, many IPW are designed to lower injuries to the knee joint. Research has shown that knee-focused IPW can successfully lower injuries in contact sports (Van Beijsterveldt et al., 2012; Waldén et al., 2012). Exercises from these IPW that are most relevant to grappling can be included in the current IPW.

Section 3: Developing an injury prevention warm-up.

Barriers and facilitators of introducing injury prevention warm-up.

Barriers to injury prevention

There are some frequently reported barriers to compliance with injury prevention programmes in sports. Minnig et al. (2022) review of the barriers to adopting evidence-based injury prevention programmes states perceived time, financial cost, coaches' competence and the inclusion of exercises that were difficult or confusing to follow. Studies not included in the review stated similar barriers, such as athletes not knowing what to do, not having been previously injured/recognition of potential value, not having the correct equipment or a lack of knowledge from coaches on how to implement the programme (Donaldson et al., 2018; Fokkema et al., 2019; Richmond et al., 2020).

Facilitators of injury prevention

Research on the barriers and facilitators of injury prevention programmes has stated that coach education is a major contributor to improving compliance (Donaldson et al., 2018; Padua et al., 2014; Richmond et al., 2020). This encompasses embedding the injury prevention warm-up (IPW) into the British wrestling coaching course, as seen in FIFA coaching licence courses and the FIFA 11+ IPW. The IPW can also be available as an online continuous professional development course (CPD) for international grappling coaches.

To overcome other barriers, such as lack of time (Donaldson et al., 2018; Minnig et al., 2022), costs (Dix et al., 2021), scheduling (O'Brien et al., 2021), and equipment (Richmond et al., 2020), the IPW is designed to last 15 to 20 minutes and will occur at the start of scheduled training sessions or completions. The IPW will not need any equipment and can be implemented by coaches to minimise the cost of hiring S&C coaches or physiotherapists. It has been stated that athletes and coaches perceive performance increases as a higher motivation than injury prevention (Bolling et al., 2020). Research has shown that associating injury prevention programmes with increased performance benefits increases compliance rates (DiStefano et al., 2010; Gomes Neto et al., 2017; Noyes & Barber Westin, 2012). Due to this, the IPW will be designed in the Raise, Activate/ Mobilise and Potentiate (RAMP) (Jeffreys, 2006) structure, which will be used as it was designed to optimise performance preparation (Jeffreys, 2006). The IPW also includes Plyometric and post-activation potentiation enhancement (PAPE) techniques that have been shown to increase athletic performance (DiStefano et al., 2010; Finlay et al., 2022; Gomes Neto et al., 2017).

Previous injury prevention models

Several injury prevention models have been proposed to understand the injury problems within athletic cohorts (Finch, 2006; Van Mechelen et al., 1992). A contemporary model is the Team-Sport Injury Prevention (TIP) cycle (O'Brien et al., 2019) that describes the process of development of an evidence-based injury prevention programme. TIP identifies the stages of designing an injury prevention programme as (re)evaluate, Identify, and intervene(O'Brien et al., 2019) (Figure 1). TIP was used in this review to gather the prior information needed to aid in the design of the IPW.

Knowledge Transfer group

Once the injury sites, types, MOIs, risk factors and barriers to compliance had been established, a knowledge transfer group (KTG) (Von Gerhardt et al., 2020) was established. This consisted of sports medicine practitioners and lecturers, sports physiology practitioners and lecturers, a United World Wrestling (UWW) physician, the chief medical officer for the British Wrestling Association (BWA), the Head of Sports medicine and performance for BWA, grappling coaches from BJJ, sambo, catch wrestling, freestyle wrestling, MMA and judo and sports therapists and performance coaches with experience of designing injury prevention programmes for professional sports teams. The TIP cycle review was sent to all members of the KTG with a request for suggestions for exercises that would be relevant to the IPW.

Appraising evidence for warm-up intervention protocols

Duration and protocol

A frequently reported barrier to injury prevention programmes is perceived time and scheduling (Donaldson et al., 2018; Minnig et al., 2022; O'Brien et al., 2021), so keeping the IPW protocol compact is a requirement that may help with compliance from coaches and grapplers. A 2016 systematic review on the effect of team warm-ups by Silva et al. (2018) found that a warm-up protocol of 15 minutes was the optimal period to increase explosive performance. To reduce injury kinematic and kinetic dysfunctions associated with injury risk factors and injury incidence, previous studies have found that an IPW timeframe of between 15 to 20 minutes is required (Belcher et al., 2021; Celebrini et al., 2014; Colclough et al., 2018; Ding et al., 2022; Lindblom et al., 2020; Nuhu et al., 2021). Furthermore, previous studies have shown that a minimum weekly frequency of 2 times a

week is needed for IPW to be effective (Celebrini et al., 2014; Ding et al., 2022; Silvers-Granelli et al., 2015; Thorborg et al., 2017).

The RAMP warm-up protocol has successfully increased performance variables in combat and contact sports such as judo, rugby league, and boxing (Eken et al., 2020; Finlay et al., 2022; Jeffreys, 2017). The rationale for the activities included in the IPW is formatted in the structure of the RAMP protocol.

Raise

The raise section aims to elevate body temperature, heart rate, respiration rate, blood flow, and joint fluid viscosity via low-intensity activities (Jeffreys, 2006). Reviews have shown that effective warm-up protocols increase the intensity until a heart rate similar to that of a competitive environment is reached (Silva et al., 2018). Research has recorded an average heart rate of 180 to 182 bpm in grappling matches and can reach a maximum of 190 – 200 (Degoutte et al., 2003; Hernández-García et al., 2009). Exercises such as high knees, heels to glutes, and head rolls have increased dynamic mobility of the spine and peripheral joints (Bizzini & Dvorak, 2015). Meanwhile, rolling has been shown to increase proprioception and postural control (Anderson et al., 2022; Seyedi et al., 2023), with regular training of rolling techniques in Judo demonstrating decreases in head PRTA when colliding with the mat (Ishikawa et al., 2018; Koshida et al., 2014; Murayama et al., 2020). Additionally, grapplers need the ability to produce a rate of force development and acceleration for movements such as takedowns (Yamashita et al., 2020). Shuffle sprints will help with the rate of force development (Markström & Olsson, 2013) and aid in increasing HR.

Activate

The activate section focuses on identifying the key muscles needed for grappling and then using a selection of dynamic movements to activate them (Fradkin et al., 2010). The physical demands of grappling involve all major muscle groups (Andreato et al., 2011; Kraemer et al., 2004). This section of the IPW will start with walking lunges with trunk rotation. Previous studies using surface electromyography (EMG)have demonstrated that forward lunges increased activation in the vastus medialis and gluteus medius. Additionally, lunges have been used effectively in peer-reviewed injury prevention and performance warm-ups (Daneshjoo et al., 2013; Jönhagen et al., 2009; Stastny et al., 2015). The lunges will be followed by bear crawls, which have been used in wrestling and functional training settings to activate the wrists, pelvis and lower limbs (Childs, 2001; Hernández-Lougedo et al., 2021). Sports specific movements have been shown to be effective in previous injury prevention programmes (Cumps et al., 2007). The wheelbarrow position mimics wrestling positions that require the grappler to support their body weight with their upper extremities(Grindstaff & Potach, 2006). Research using EMG has shown that press up variations, such as the wheelbarrow exercise activated the lower trapezius and the serratus anterior (Andersen et al., 2012). Press-ups have been demonstrated to increase upper body and core activation (Gouvali & Boudolos, 2005; Snarr & Esco, 2013; Youdas et al., 2010) and have been used effectively in injury prevention warm-ups (McCrary et al., 2015). Hindu press-ups involve a significant degree of trunk and hip flexion that mimics the 110 degrees of trunk/hip flexion seen in the biomechanical analysis of a sprawl (Denning, 2017). Much like the Hindu press-up, Hindu squats are commonly used in various wrestling styles. The squat has been successfully used to lower injury prevention and increase performance in the FIFA 11 + protocol (Barengo et al., 2014; Hwang et al., 2019). The Hindu squat also allows grapplers to move into greater degrees of knee flexion needed to perform movements such as the double leg takedown (147 degrees) (Denning, 2017). Research has shown that many head, neck and trunk injuries in BJJ are a result of landing (Stephenson & Rossheim, 2018). It has been recommended that increased training in landing techniques will aid in preventing landing and fall injuries, as previously demonstrated in judo (Koshida et al., 2017; Lockhart et al., 2022; Stephenson & Rossheim, 2018).

Short-term breakfall practice has improved surface EMG activity in sternocleidomastoid, external oblique and rectus abdominis muscles (Koshida & Matsuda, 2012).

Mobilise

The lack of mobility has been acknowledged as an injury precursor in grappling sports (Hinz et al., 2021). Additionally, it has been shown that grappling requires athletes to exert force in large degrees of an athlete's range of movement (ROM). This can be seen in suplexes in greco-roman wrestling (Hoffmann et al., 2023), throws in judo (Lockhart et al., 2022), bridges in Swiss wrestling (Lorenzetti et al., 2020) and shooting for takedowns in BJJ and freestyle wrestling (Denning, 2017; Yamashita et al., 2020). Biomechanical analysis of greco-roman wrestling has shown that many trajectories from throws, takedowns and presses follow circular and helicoidal paths, resulting in hip and spinal rotation (Sacripanti, 1988). Therefore, the IPW adopts the scorpion exercise to increase ROM in these areas. Neck mobilisations are also required as research has shown that neck strengthening reduces cervical injuries in combat sports (Liu, 2022) as well as sports-related concussions (Garrett et al., 2023).

Potentiate

The potentiate stage aims to increase activity to maximal intensity in preparation for competition (Jeffreys, 2006). This often includes techniques such as post-activation performance enhancement (PAPE) (Finlay et al., 2022). This technique is primarily used to improve sports performance, and the focus of the IPW is to reduce athlete injury. However, it has been shown that coaches and athletes perceive performance as a higher priority than injury prevention (Bolling et al., 2020). Finch (2006) proposal of the Translating Research into Injury Prevention Practice Framework (TRIPP) states that only research adopted by sports participants, their coaches, and sporting bodies can prevent injuries. By including performance aspects in the IPW, compliance levels are anticipated to increase. The potentiate section of the IPW starts with plyometric exercises. Plyometric training in adolescents has also been evidenced to increase neural drive to the agonist's muscles, reactive strength stretches, shorting cycle efficiency, fascicle length, and vastus lateralis pennation angle and aid in the development of muscle activation strategies (Chmielewski et al., 2006; Miller et al., 2010; Secomb et al., 2017). PAPE exercises such as plyometric press-ups have shown increases (4.9%) in peak power output (Ulrich & Parstorfer, 2017).

This section also includes partner contact drills. Wrestling and contact drills have also been recommended as injury prevention strategies for contact injuries in rugby league and union (Gabbett et al., 2012; Hollander et al., 2021). The IPW concludes with a partner reaction drill designed by the British wrestling team's coaching staff. This involves grapplers performing takedown defensive and attacking movements as they react to their partner's cues. Visual processing, visual fields, and visual reaction times are essential to the performance of numerous sports and play a role in athletic injuries (Clark et al., 2020; Swanik et al., 2007). The partnered drills also allow grapplers to raise their heart rate after an anticipated drop in the mobilise section.

Conclusion

The review of the available research shows that the knee is the most commonly injured site in freestyle wrestling (Agel et al., 2007; Jarrett et al., 1998; Kroshus et al., 2018; Powell et al., 2021; Yard et al., 2008), BJJ (Barreto et al., 2017; Hinz et al., 2021; Kreiswirth et al., 2014; Lopes et al., 2021; Nery et al., 2022; Scoggin et al., 2014; Silva Junior et al., 2018; Usuki et al., 2017), sambo (Lapaeva & Tabakov, 2021) and traditional jiu-jitsu (Sistar et al., 2023) and the leading time loss injury in judo (Akoto et al., 2017; Mooren et al., 2023). Ligament strains were reported as the leading injury type in

freestyle wrestling, BJJ (Barreto et al., 2017; De Almeida & De Araújo, 2020; Juliano Eustaquio et al., 2021) and judo (Mooren et al., 2023) and second in traditional jiu-jitsu (Nicolini et al., 2021). In greco-roman wrestling and judo competitions, the grappling sports that do not allow leg attacks, the head, neck and trunk are the leading injury sites (Akbarnejad & Sayyah, 2012; Akhmedov et al., 2016; Daneshmandi et al., 2020; Mooren et al., 2023; Sandeep & Kuloor, 2017). The available research suggests that decreased strength, power, and flexibility affect injury incident and prevalence rates.

It was established that common barriers to coach and athlete compliance with injury prevention programmes included deficiency of coach knowledge, lack of time, costs, scheduling, and equipment. The IPW was designed using the available research in grappling sports and supplemented with research into the prevention of knee and upper body fall injuries. The use of equipment was avoided to promote compliance rates. This is the first evidence-based IPW for grappling sports and may act as a resource for coaches of all grappling sports. Further studies are now needed to evaluate the efficacy of this IPW in each of the individual grappling sports.

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Figures

Figure 1. Team-Sport Injury Prevention (TIP) cycle (O'Brien et al., 2019)