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National Biomechanics Day April 7, 2021

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W E L C O M E

Professor Syamantak Bhattacharya
Pro Vice-Chancellor, Research and Knowledge Exchange, Solent University

"As Pro-Vice Chancellor for Research and Knowledge Exchange, I would like to welcome you to Solent University, where we are proud of our applied research and knowledge exchange work. We excel in a wide range of key subjects at the University and are particularly proud of Sport and Exercise Science.

We have been submitting internationally excellent and world-leading research in the national Research Excellence Framework exercises since 2014. Our knowledge exchange activities draw from our research work which received a boost in 2019 with the opening of our new Solent Sports Complex, bringing together cutting-edge equipment and facilities. I am proud of Solent University hosting this Biomechanics Interest Group Conference and wish this event a great success."

Dr Andrew Mitchell
Chair, BASES Division of Biomechanics and Motor Behaviour

"As Chair of the BASES Division of Biomechanics and Motor Behaviour I would like to welcome you to BIG2021. Whilst I have been attending BASES Student Conferences for 20 years and BASES Annual Conferences for nearly 30 years, the BIG events have always been a highlight of the calendar, that I have encouraged both my staff and students to attend.

I would like to congratulate the BIG2021 organising committee on putting together such an exciting event, so perfectly timed with the National Biomechanics Day (NBD) initiative, with a good range of disciplines represented alongside some world-class keynote speakers. I am hoping you find the content of the BIG2021 event both interesting and inspiring."

Associate Professor Adam Hawkey FBASES
BASES Biomechanics Interest Group/BASES BIG2021 Chair, Solent University

"As Chair of the BASES BIG2021 event, I welcome you to Solent University. Run in partnership with the National Biomechanics Day initiative and the International Sports Engineering Association (ISEA) this global event celebrates biomechanics as the 'breakthrough science of the 21st century'.

I am delighted to welcome some truly world-leading speakers to present at this event: Professor Janie L Wilson from McMaster University (and President of the Canadian Society for Biomechanics); Dr Philip Graham-Smith from Aspire Academy in Qatar; Dr Martin Warner from the University of Southampton; and Dr Laura Jade Elstub, Shane King, Maura Eveld, and Cameron Nurse and Rachel Teater from the CREATe laboratory at Vanderbilt University. We have put together an exciting programme and I hope that you enjoy BASES BIG2021 and all that the event has to offer."

KEYNOTE SPEAKERS

Professor Janie L Wilson
is Professor of Surgery, Biomedical Engineering, and Mechanical Engineering, at McMaster University, Canada. Here she runs a multidisciplinary research program in human movement biomechanics. She is President of the Canadian Society for Biomechanics and a past President of the Canadian Orthopaedic Research Society.

Dr Philip Graham-Smith
is Head of Biomechanics and Innovation at Aspire Academy in Qatar. He is the former Consultant Head of Biomechanics to the English Institute of Sport. He is also a Fellow of BASES, a British Olympic Association (BOA) registered Performance Analyst, and a Certified Strength and Conditioning Specialists®.

Dr Martin Warner
is a Lecturer in Health Sciences at the University of Southampton and works within the Centre for Sport, Exercise and Osteoarthritis Versus Arthritis. Martin's research experience involves understanding the biomechanical mechanisms of joint dysfunction, specifically the upper limb and shoulder, in sport and physical activity.

Dr Laura Jade Elstub
is a Postdoctoral Research Scholar in the Center for Rehabilitation Engineering and Assistive Technology (CREATe) laboratory at Vanderbilt University, where her research focuses on the development of wearable technology and exosuits to decrease injury risk in a range of different populations and use cases.

Shane King
is a PhD student in mechanical engineering in the CREATe laboratory at Vanderbilt University, studying the human stumble recovery response, the biomechanical analysis of the stumble response and the design and validation of a stumble recovery controller for a powered knee prosthesis.

Maura Eveld
is a PhD student in mechanical engineering in the CREATe laboratory at Vanderbilt University, where she studies the biomechanics of stumble recovery, using experimental insights to design and control assistive technology interventions (for example prostheses and exoskeletons) that can reduce fall risk.

Cameron Nurse
is a PhD student in mechanical engineering in the CREATe laboratory at Vanderbilt University, where his research focuses on developing and assessing wearable technology to mitigate injury and improve performance.

Rachel Teater
is a PhD student in mechanical engineering in the CREATe laboratory at Vanderbilt University, where her research focuses on developing and evaluating ankle-foot prostheses to improve the mobility of transtibial prosthetic device users.

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Garry Halsey

BA (Hons) Football Studies, 2014,
Education Development Coordinator, FA Education

Solent University helped me to gain invaluable work experience and contacts within the professional game, as well as knowledge surrounding both professional and grassroots football. Without my time at Solent, I would not have the confidence I now have in my abilities and understanding of the game.

HISTORICAL DEVELOPMENT OF THE TENNIS RACKET

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Tennis racket design has changed considerably from its conception by Major Wingfield in the 1870s. The first rackets were wooden with small lopsided heads. From the 1900s to the 1960s, rackets tended to be wooden with small, symmetrical heads; and there were limited design developments in this period. However, a step-change in tennis racket design occurred in the late 1960s, when experimentation with alternative materials coincided with increased competition and interest from the introduction of the Open Era. Engineers employed materials like aluminium, steel and fibreglass as they developed stiffer rackets with larger heads, making it easier to play the game. Fibre-polymer composites emerged as the dominant material for high-end tennis rackets in the late 1980s. These modern composite tennis rackets are lighter and stiffer and have larger heads than their wooden predecessors. These changes in tennis racket shape and material have important implications for the game, including for player performance and injury risk, regulation, officiating and spectator experience (Miller S, 2006, British Journal of Sports Med, 40, 401). The aim of this work is to quantify how tennis rackets have changed since the 1870s, with a view to furthering our understanding of how such developments have influenced the game. Five-hundred and twenty five rackets dating from 1874 to 2017 were characterised at a number of collections, including the Wimbledon Lawn Tennis Museum, the International Tennis Federation and HEAD Sports (Taraborrelli et al., 2019, Applied Sciences, 9, 4352). We applied, i) uniform beam models to describe how the stiffness of these rackets has changed and ii) morphometric analysis to describe how the shape of these rackets has changed. The results showed that the shift in materials over time has influenced both the stiffness and shape of tennis rackets. Modern composite rackets are typically about twice as stiff as their wooden predecessors and they are lighter with larger and more ovoid heads, with the widest point further from the handle. Stiff, lightweight modern rackets which allow the player to hit the ball further "off-centre" may increase injury risk to the upper extremity (Miller S, 2006, British Journal of Sports Med, 40, 401), and this will be assessed in future work.

USING A STAIR HORIZONTAL-VERTICAL ILLUSION TO INCREASE FOOT CLEARANCE OVER AN INCONSISTENTLY TALLER STAIR-RISER

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Stair falls can lead to serious injury and in some cases can be fatal. This can be caused by issues with the stair-built environment such as inconsistent step risers. Inconsistently taller mid-stair risers reduce foot clearance as the step height change often goes visually unnoticed due to the somatosensory adaptation, increasing the risk of a toe catch. A stair horizontal-vertical illusion can increase both perceived step riser height and foot clearance during a step up and could help offset the reduced foot clearances. This study aimed to determine whether a stair horizontal-vertical illusion increases foot clearance over an inconsistently taller mid-stair riser and whether this interfered with typical measures of stair ascent safety. Twelve participants (age: 22 ± 3 years) ascended a seven-step staircase under three conditions i) all steps consistent in riser height (consistent), ii) a 1cm increase in step 5 riser height only (inconsistent), and iii) a 1cm increase in step 5 riser height only, superimposed with a stair horizontal-vertical illusion (illusion). Measures of stair safety (vertical foot clearance, foot overhang, margins of stability), captured by Vicon, were assessed over step 4, 5 and 6. Perceived riser height was determined using a computer-based perception test comparing images of the stair horizontal-vertical illusion to plain stair images. A One-Way Repeated Measures ANOVA compared stair safety between conditions. A One Sample t test compared perceived step riser height to the veridical. Over step 5, foot clearance reduced by 0.8cm for the inconsistent compared to consistent condition. The illusion increased foot clearance by 1.1cm and decreased foot overhang by 4% compared to the inconsistent condition. The illusion increased perceived riser height by 12%. On step 4, the illusion decreased anterior stability compared to the inconsistent condition. Medio-lateral stability was greater in the inconsistent and illusion condition compared to the consistent condition. A stair horizontal-vertical illusion increased foot clearances, offsetting the decreases found over an inconsistently taller riser. The stair horizontal-vertical illusion could be a useful visual modification on stairs with inconsistently taller risers, particularly on older stairs where a rebuild is not always possible. Future studies should assess the efficacy of the illusion on public stairs.

HAND CARRYING ITEMS AFFECTS LOWER LIMB KINEMATICS DURING RUNNING

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With participation in marathon running increasing annually (Aicher et al., 2017, *Journal of Global Sport Management, 2,* 217–233), and ≤ 90% of those training for a marathon experiencing injury (Van Gent et al., 2007, *British Journal of Sports Medicine, 41*(8), 469–480), determining methods to reduce injury and improve efficiency are desirable. Current evidence suggests that a combination of high cadence, short stride-length, low ground contact-time, and high flight-time are most effective at improving running efficiency and reducing injury risk. There is limited research investigating the role of the arms on overall running economy. Arm kinematics in recreational runners is often limited by carrying items in the hands (e.g. water bottle and/or a Smartphone). This current study examined the effect of hand-carrying such items on lower limb kinematics. Following institutional ethics approval, four (n = 4) healthy male recreational runners (mean ± SD: age = 41 ± 6 yrs.; height = 1.77 ± 0.02 m; mass = 74.4 ± 2.1 kg; average weekly mileage = 15.75 ± 3.64 mi) ran on a treadmill, at their preferred running speed (PRS), for one-minute bouts in each of seven different conditions: control (nothing in the hands); water bottle in left hand (WBLH); water bottle in right hand (WBRH); phone in left hand (PLH); phone in right hand (PRH); water bottle in left, phone in right hand (WBLPRH); phone in left, water bottle in right hand (PLWBRH). Flight-time, contact-time, height, cadence, and stride-length were recorded for each condition using an Optojump system (Microgate, Bolzano, Italy) mounted on the side of the treadmill. Repeated measures ANOVA revealed no-significant differences ($P > 0.05$) between each dependent variable when compared to the control (flight- time $P = 0.329$, contact-time $P = 0.731$, height $P = 0.643$, stride-length $P = 0.282$, cadence $P = 0.243$), although given the low sample size of this pilot study, having high P values is unlikely to be meaningful. However, individual participant differences in compensation for each condition were identified with high standard deviation from the mean, for example; WBLHPR (mean ± SD: cadence = −2.78 ± 20.27 steps/ min; height = 2.56 ± 1.79 cm; stride-length = −2.28 ± 2.78 cm). The WBLPRH condition accumulated the greatest net change to measures. A notable trend towards increasing stride- length and reducing cadence was observed. With research suggesting that this combination of compensations is unfavourable, and with the popularity and participation in running increasing per annum, further research utilising a greater number of runners (for a power level of >0.8) is now required to allow greater comparison of the different carrying conditions and the effect these have on lower limb kinematics.

PARTICIPANTS EXPOSED TO FORWARD FALLING SLIP-LIKE PERTURBATIONS IMPROVE THEIR BALANCE WITH REPEATED EXPOSURE; A STUDY OF THE UNDERPINNING BIOMECHANICAL MECHANISMS.

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Repeated exposure to forward falling slips (FFSs) improves balance recovery when participants are exposed to multiple perturbations (McCrum et al. , 2018, *Communications Biology*, 1, 230) but the recovery mechanisms involved, remain unknown. This limits the development of specifically targeted fall-prevention interventions that train people to recover from gait perturbations. To improve these, we aimed to understand the recovery strategies developed when participants were exposed to repeated FFSs.With ethical approval, we exposed seventeen young and seventeen older adults to 10 FFSs, which were simulated by accelerating one side of a split-belt treadmill to cause a forwad loss of balance in late stance (Debelle et al., 2020, *Frontiers in Sports and Active Living*, 2, 82). We measured balance as the margin of stability (MoS) at heel-strike of the first two recovery steps (Rec1 and Rec2). To understand the underlying biomechanical changes with repeated perturbations, we measured hip, knee and ankle moments, sagittal angle of the GRF vector and step length (% body-height) during the perturbed step (Pert), Rec1 and Rec2. We evaluated the effects of Age and Steps using Mixed-Design Anovas and non-parametric equivalents, recovery steps were also compared with Normal (average of 5 gait cycles collected before Slip01). The effect of each variable on the MoS was measured using bivariate correlations. We found no significant effect of age. MoS was lower than Normal in Slip01_Rec1 and Slip10_Rec1($p<0.001$). MoS in Rec2 was lower than Normal for Slip01($p<0.001$), but not for Slip10. Compared to Normal, during Slip01 participants developed on average a more posteriorly oriented GRF angle at mid-stance of Pert($p<0.001$), lower plantarflexor moments during Pert and Rec1($p=0.002$), higher knee extensor moments during Rec1($p=0.002$), and took a shorter step during Rec1($p<0.001$). Apart from the GRF angle in Pert, these variables returned to Normal levels by Slip10. Correlation analysis showed that the participants who had the best balance were those who had the most posteriorly directed GRF vector in Pert($r=-0.534$, $p=0.001$), the highest plantarflexor moments in Pert and Rec1($0.388<r<0.497$, $p\leq0.023$), the lowest knee extensor moments in Rec1($r=-0.434$, $p=0.010$), and who took the longest steps in Rec1($r=0.648$, $p<0.001$). The recovery strategy developed at first exposure was, in many ways, counter-productive but was optimised with repeated exposure. As it is well correlated with balance and easily coachable, interventions aiming to decrease fall risks following an FFS should focus on maintaining step length near normal, particularly on the first recovery step.

THE USE OF WEARABLE DEVICES FOR RUNNING GAIT ANALYSIS: A SYSTEMATIC REVIEW.

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Running gait assessment has traditionally been performed using subjective observation or expensive laboratory-based objective technologies, such as 3D motion capture or force plates. However, recent developments in wearable technology allow for continuous monitoring and analysis of running mechanics in any environment. Objective measurement of running gait is an important clinical tool for injury assessment and provides metrics that can be used to enhance performance. Therefore, the aim of this systematic review was to identify how wearable devices are being used for running gait analysis in adults. A systematic search of literature was conducted in the following scientific databases: PubMed, Scopus, WebofScience, and SportDiscus. Information was extracted from each included article regarding the type of study, participants, protocol, wearable sensor(s), main outcome measures, analysis, and key findings. A total of 220 articles were reviewed: 45 focused solely on validity and/or reliability of the sensors, 113 focused on applied use, 25 incorporated both validity and reliability and applied use. Most studies used inertial measurement unit (IMU) sensors (primarily accelerometers), with only 17 using pressure insoles. Sensor locations were distributed among the shank, foot, and the waist/lower back/pelvis. The mean number of participants was 29 (± 16), with an average age of 27.9 (± 6.5years), with only 4 studies examining female participants. Most studies took place indoors, using a treadmill, performed retrospective group-based analyses, with the main aims seeking to identify running gait characteristics, determine injury status, investigate experience level on running gait or characterise the effects of fatigue. Generally, wearable devices were found to be valid and reliable tools for assessing running gait compared to reference standards. Despite the advancements in wearable-specific metrics for running gait analysis, there is a need for prospective, subject and sub-group specific investigations that analyse running gait over prolonged periods, among larger numbers of participants, and in natural running environments. The development of multi-modal wearable technology to give a more comprehensive analysis of running gait would further aid analysis outside of the laboratory. Furthermore, consensus regarding terminology, testing validity and reliability of devices and suitability of performance metrics needs to be established. Recommendations for future studies examining wearables for running gait assessment are provided and discussed.

INVESTIGATION OF THE CONSISTENCY OF WEARABLE IMU SIGNAL OUTPUTS FOR ANALYSING GOLF BIOMECHANICS.

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Golf is a technically demanding sport, which requires the coordinated actions of all body parts and the golf club. A successful golf shot is dependent upon multiple biomechanical factors and is determined by the distance and accuracy of golf ball displacement. Golfers and golf coaches use a variety of methods in order to appraise performance, including emerging inertial measurement unit (IMU) technologies (King *et al.*, 2008, *Sensors and Actuators A*, 141, 619-630). However, the majority of these novel systems are based on inertial sensors mounted on or within the golf club, as opposed to wearable systems. The aim of this study was to investigate if a golf shot can be identified consistently from the IMU signal output of a body-worn device. Two golfers of differing abilities volunteered to take part in this feasibility study (1 male, 25 years, 7 handicap; and 1 female, 59 years, 16 handicap). An IMU (Shimmer3 Consensys, Shimmer Research Ltd., Ireland) offering 9 DoF inertial sensing at 100 Hz via accelerometer (±16 *g*), gyroscope (±2,000 $°\cdot s^{-1}$) and magnetometer (±49.152 gauss), was positioned at various positions on the body (including forearm, lower back and upper leg) whilst participants performed 10 trials with each of three different golf clubs (driver, 6 iron, pitching wedge). The primary measurements recorded were linear acceleration ($m\cdot s^{-2}$) and angular velocity ($°\cdot s^{-1}$), with vertical, anteroposterior and mediolateral axes isolated and examined for consistency. Factor analysis determined that the dorsal surface of the leading forearm offers the most appropriate location because it produced the most consistent signal output both between and within participants ($r = 0.820$, $P < 0.05$), allowing for the identification of backswing, ball impact and follow through. Additionally, golf shots performed using different golf clubs and performed by different participants were also identifiable. The implications of this study are that wearable IMU technology may offer a novel method for the development of automatic feature detection algorithms for the biomechanical analysis of golf performance. These algorithms may focus on the key performance indicators identified by coaches as being most highly correlated with success in golf, such as rotation of body parts, postural balance and the speed and timing of coordinated actions, facilitating real-time feedback to coach and golfer and overcoming the limitations of traditional video-based approaches. Development work is underway to investigate this further in laboratory and applied settings.

IN VIVO OPERATING LENGTH OF THE GASTROCNEMIUS MEDIALIS MUSCLE DURING GAIT IN CHILDREN WHO IDIOPATHICALLY TOE-WALK .

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In typically developed gait, the gastrocnemius medialis muscle operates close to optimal sarcomere length, utilising joint angles that favour the economical production of high contractile force (Fukunaga et al., 2001, *Proceedings of the Royal Society of London. Series B: Biological Sciences,* 268, 229-233) . Children who idiopathically toe-walk (ITW) habitually walk at greater plantarflexion angles than typically developing (TD) children, which likely results in shorter gastrocnemius fascicle lengths. Consequently, this may suggest that the sarcomeres of children who ITW operate at shorter lengths than optimal (Arnold and Delp, 2011, *Philosophical Transactions of the Royal Society B: Biological Sciences,* 366, 1530-1539) . However, the gastrocnemius fascicle lengths of children who ITW, and their operating range on the force-length relationship during gait have never been measured. Thus, it is unknown how the altered muscle lengths relate to dynamic muscle function, despite being directly targeted by clinical treatments. With NHS ethical approval, five children who ITW (age 8±2yrs; height 1.38±0.15m; mass 45.2±26.7kg) and 14 TD children (age 10±2yrs; height 1.39±0.11m; mass 37.8±17.5kg) completed a gait analysis, from which ankle kinematics and kinetics were calculated. Simultaneously, gastrocnemius fascicle behaviour was measured using ultrasound. In a second session, the plantarflexor moment-angle and -length relationships were determined from isometric maximum voluntary contractions (MVC) at 6 positions across full range of motion (ROM) , on an isokinetic dynamometer combined with ultrasound. Statistical parametric mapping found that during gait, children who ITW operated at more plantarflexed angles ($p=0.013$) and longer fascicle lengths ($p=0.008$) than TD children. This coincided with alterations in the moment-angle and -length relationships measured during MVC. Peak plantarflexor moment occurred at significantly more plantarflexed angles in children who ITW ($p=0.010$) , and at longer fascicle lengths ($p=0.001$) than TD children. This study established that the ankle ROM and associated gastrocnemius fascicle lengths that children who ITW utilise during gait correspond to operating regions near the peak of the force-length relationship, similarly to TD children. This is despite longer muscle lengths at more plantarflexed joint positions in children who ITW. Thus, the current study indicates that children who ITW present with substantial alterations in the gastrocnemius functional properties, which appear well adapted to the characteristic demands of equinus gait. Our findings suggest that surgical procedures to lengthen the gastrocnemius muscle to correct toe-walking may have negative short-term consequences on muscle function. This may contribute to the poor medium to long-term effectiveness of such interventions in these children.

QUANTIFYING WRIST MOTION IN BOXING.

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The hand is reported as the most common injury site in boxing, with a longer time loss than any other area in this sport (Loosemore et al, 2017, Hand, 12, 181–187) . The amount of wrist motion, specifically flexion, has been stated as contributing to these injuries (Noble, American Journal of Sports Medicine, 1987, 15, 342-346), yet there is no literature available to quantify wrist kinematics on impact in boxing. The aims of this paper were to identify if in boxing on impact; a) ulnoflexion motion occurs in straight (Jab) and bent arm (Hook) shots, b) identify the amount of wrist angular excursion for Jab and Hook shots, and c) identify if more wrist angular excursion occurs in Jab than Hook shots. Two types of shots, Jab and Hook shots, were assessed during *in-vivo* testing procedures. With institutional ethical approval, 23 men and 6 women orthodox stance boxers right-arm dominant and orthodox stance (left-hand leading) boxers (mean age: 24 ± 4 years; stature: 1.78 ± 0.10m; mass 71 ± 17 kg) (mean ± s), forming part of the National Olympic Great Britain squad, were asked to throw Jab and Hook shots with their lead arm. Jab shots were performed six times, allowing a break of about three seconds between shots. The same procedure was repeated for Hook shots in the same session. To measure wrist excursion on impact, similar equipment to a previous study was used showing good accuracy and good to substantial reliability for Jab and Hook shots (Gatt, Allen and Wheat, 2019, Sports Engineering, 2019). For both Jab and Hook shots, flexion and ulnar deviation were coupled on impact, with a mean and standard deviation of 9.3±2.0° and 4.7±1.2° respectively for Jab shots, and 5.5±1.1° and 3.3±0.9° respectively for Hook shots, supporting dart throwing motion at the wrist. For both shot types, wrist angular excursion on impact occurred within >30% of the total available active range of motion, with wrist angles greater in both flexion ($t=9.0$, $p<0.001$, $d=1.7$) and ulnar deviation ($t=8.4$, $p<0.001$, $d=1.6$) for Jab than Hook shots. This study provides useful information on wrist kinematics during the impact phase of punching and potentially an improved understanding of injury mechanisms in boxing. Further research, however, is warranted to identify strategies that can influence the kinematics of the wrist on impact in boxing.

DOES INCREASED SIMULATED BREAST MASS CHANGE POSTERIOR TRUNK MUSCULAR ACTIVITY?

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Correct posture refers to the plumb line position the body is held when sitting or standing, requiring sufficient muscular strength and endurance to minimise excessive stress on the body. Deviations from alignment can increase posterior trunk muscular activity. Additionally, breast mass (augmentation/ hypertrophy) can alter the trunk centre of gravity, causing changes in posture, potentially leading to back pain. To maintain correct posture, posterior muscular activity may increase to counteract increased anterior breast mass. This study aimed to investigate the effect of increasing simulated breast mass and correcting breast mass asymmetry on back extensor muscle activity. Following institutional ethical approval and written informed consent, 8 females: mass (75 ± 7 kg), stature (168 ± 7 cm), under band (82 ± 4 cm), over bust (99 ± 5 cm), bra size (30 D to 34 E) consented to take part. Simulated breast mass was altered by adding mass as a percentage increase (0-150%) from participants natural breast mass, as estimated from a 3D breast scan. 5 Qualisys cameras (250 Hz) provided real-time feedback of the postural plumb line (ear lobe, glenohumeral joint, greater trochanter, lateral femoral epicondyle, and lateral malleolus) to standardise posture. Simultaneously, 8 EMG sensors (1000 Hz), placed bi-laterally on the upper and lower trapezius and erector spinae, recorded muscle activation during 2 minutes of sitting and standing. Mean EMG data were calculated, and a Pearson correlation tested for a relationship between mean muscle activity and breast mass change. Muscle asymmetry was calculated using the symmetry angle equation where no significant group differences were found between no mass and 150% mass conditions. A small positive correlation ($0.10 \leq r < 0.30$) between muscle activity and simulated breast mass was identified in all muscles during sitting and in two muscles, left upper erector spinae and the right upper trapezius, during standing. Increased breast mass is associated with small increases in muscle activity, suggesting that muscles may work harder to maintain posture with an additional anterior load, potentially altering spinal loading. Therefore, it is suggested that a lighter weight implant be considered for breast augmentation to minimise the increases in muscle activity required to maintain correct posture.

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