The Oral Health of Elite Athletes in Ireland.

A thesis submitted to the University of Dublin in partial fulfilment of the degree of Doctorate in Dental Surgery D.Ch.Dent. (Prosthodontics)

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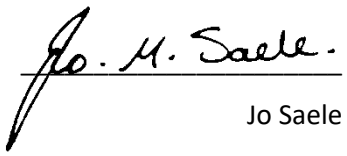

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Summary

Background

The oral cavity has been described as the window to general health as many diseases and medications can impact the oral cavity (Kane 2017). There is a greater appreciation that these oral conditions can have a greater systemic impact than appreciated in the past. These conventional unidimensional concepts of health have been replaced by a more holistic approach (Brondani and MacEntee 2014). This is surprising as the Greek philosopher, Aristotle, coined the phrase 'the whole is more than the sum of its parts' which is much like how overall health and well-being is viewed today.

Athlete diet and training regimes have been tailored to achieving optimal physical performance (Barr and Rideout 2004). Unfortunately, the importance of elite athlete oral health for peak-performance to date has been widely underappreciated. Fortunately, as more research is published, more governing bodies and sporting bodies are advocating the importance of oral health in elite athletes due to their potential increased exposure to risk factors of oral diseases (Tripodi et al. 2021).

However, few studies have examined oral health directly and no such studies have specifically focused on Irish elite athletes. Therefore, the aim of this study was to describe the oral health of elite athletes in Ireland, describe current oral health practices and habits and evaluate the impact elite athlete's oral health had on training and performance.

Methods

This was a cross sectional observational study undertaken at two training facilities in Ireland; Participant information leaflets were distributed to Irish elite athletes involved with Sport Ireland (formerly the Irish Sports Council) inviting them to participate in the study. Ethical approval was granted by Trinity College Dublin Faculty Research Ethics Committee; ref: 210910. Following receipt of informed consent, a standardised clinical history and examination was collected followed by a brief questionnaire. Data was electronically collected using open-source software, KoBoToolbox (Kobo Inc, USA).

Results

In total, 88 athletes from 8 sports; Boxing (22), Rowing (21), Cycling (1), Swimming (5), Paracycling (6), Cricket (31), Gymnastics (1), Triathlon (1), were recruited and examined clinically. Overall, the results demonstrated fair to poor oral health. Dental caries was present in 72.7% of athletes, with an average of 1.75 teeth per athlete requiring restorative intervention. Dental erosion was present in 19.3% and periodontal disease (gingivitis 46.6%, periodontitis 53.4%).

In total, 39.8% of athletes had experienced pain from their mouth, teeth or gums in the last 12 months. These findings were largely in agreement with previous research carried out at the London 2012 Olympic Games (Needleman et al. 2013). However, athletes presented with more natural teeth on average (30.1) than the 25.1 natural teeth on average reported in the general Northern Ireland population as part of the most recent Adult Dental Health Survey in 2009 where they were included (Health and Social Care Information Centre, 2009). There was also a higher proportion of athletes (94.3%) that presented with 18 or more sound untreated teeth comparted with the 39% of the general Northern Irish population (Health and Social Care Information Centre, 2009). However, there was a much higher prevalence of bleeding on probing (80.7% vs 64%) in the elite athlete population and higher proportion of erosion (19.3% vs 15%).

Conclusions

The oral health of Irish elite athletes attending both training facilities for clinical examination was generally poor, resulting in substantial negative impacts on training and performance. Further research in this field is clearly needed; involving a greater number of athletes and wider variety of sporting disciplines. Health promotion and disease prevention interventions are urgently required to meet the needs of elite athletes in Ireland.

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I dedicate this thesis to all of you, with heartfelt appreciation for being my unbreakable support system.

Table of Contents

Contents

List of Figures

List of Tables

Appendix

List of Abbreviations

AAP: American Academy of Periodontology

ADA: American Dental Association

BEWE: Basic Erosive Wear Examination

BOP: Bleeding on probing

BPE: Basic Periodontal Examination

COM-B: Capability, opportunity, motivation behaviour change model

CPI: Community Periodontal Index

CPITN: Community Periodontal Index of Treatment Need

CSDH: Commission on Social Determinants of Health

DMFT: Decayed Missing Filled Teeth

EDC: Electronic data capture

HER: Electronic Health Records

FDI: World Dental Federation

GDPR: General Data Protection Regulation

GUI: Golfing Union of Ireland

HFCS: High-fructose corn syrup

HHI: Harvard Humanitarian Initiative

HRQoL: Health Related Quality of Life

ICDAS: International Caries Detection and Assessment System

IOC: International Olympics Committee

IRFU: Irish Rugby Football Union

NHS: National Health Service

NI: Northern Ireland

OCHA: Office for the Coordination of Humanitarian Affairs

OHI: Oral Health Impacts

OHIP-14: Modified Oral Health Impact Profile Questionnaire (14 questions)

OHIP-49:Oral Health Impact Profile Questionnaire (Full questionnaire)

OHIP: Oral Health Impact Profile

OHRQoL: Oral Health Related Quality of Life

PDC: Paper-based data capture

PSR: Periodontal Screening and Recording

QoL: Quality of Life

RoI: Republic of Ireland

TMD: Temporomandibular Joint Disorder

TMJ: Temporomandibular Joint

UK: United Kingdom

WADA: World Anti-Doping Agency

WHO: World Health Organisation

1. Literature Review

1.1 Introduction

Oral health is integral to general health and well-being and an integral part of an athlete's ability to compete at the highest level through training and performance (Gallagher et al. 2021). An important consideration in high-performance sports is the protection of an athlete's health through prevention of injury and avoidance of ill health. In order to accurately establish the burden of health problems and inform appropriate preventative health promotion and treatment strategies it is important that high quality data on the prevalence of oral disease in this niche population is described. In addition to validated clinical measures, the use of self-reported measures of health, well-being and sports performance enables a greater understanding of issues pertaining to athletes' development and welfare (Ashley et al. 2015; Bryant et al. 2011).

Previous research has suggested that poor oral health and negative self-reported impacts are common in elite athletes (Needleman et al. 2013). However, much of the previous research used multiple examiners without reported calibration and outcomes measures of impact on performance without evidence of their validity (Gallagher et al. 2019).

Oral health promotion and monitoring is becoming increasingly important at a societal level as well as in elite athlete populations. Previous research undertaken during Olympic Games have highlighted not only the detrimental impact of dental disease but also its high prevalence. In Athens (2004) dental care was the second most requested health service after musculoskeletal reasons (Vougiouklakis et al. 2008). During the 2008 Beijing Olympic games, in the region of 1600 dental treatments were completed (Yang et al. 2011). In London, at the 2012 Olympic Games, oral disease was responsible for 30% of all medical emergencies, second only to musculoskeletal complaints in terms of attendance (Needleman et al. 2013). More recently, 43% of Dutch athletes who were eligible to compete at the Rio 2016 Olympic Games presented with dental findings necessitating intervention (Kragt et al. 2019).

Previous research has demonstrated that elite athletes have a high prevalence of oral disease and resultant impact on general health, along with negative psychosocial impacts such as difficulties eating, sleeping and socialising. They also reported sport performance impacts, including pain and difficulties with participation in training and competition (Needleman et al. 2014). This research aimed to evaluate the prevalence of oral disease in Irish elite athletes from different sporting disciplines using calibrated examiners and validated oral health indices recorded under standardised examination conditions.

1.2 Elite Athletes

1.2.1 Defining elite athletes

In Ireland, the definition of elite athletes may vary slightly depending on the sport and the organisation. Elite athletes in Ireland are those who compete at the highest level of their sport, and possess exceptional physical and mental abilities. Sport Ireland set out their definition of elite athletes in their publication of "Return to Sport Expert Group issues guidance to sports sector" where they defined elite athletes that were able to return to competition and training following easing of restrictions during the Covid pandemic (Gash 2020). This was largely based on criteria set out by Swann and colleagues, where they defined elite athletes as those who were capable of achieving success at the highest level of international competition, including Olympic and Paralympic Games, World Championships, European Championships, and other major international events (Swann et al. 2015). In Ireland, many sports have their own national governing bodies and organisations which have their own criteria. For instance, the Irish Rugby Football Union (IRFU) has a high-performance program that identifies and supports elite rugby players in the country, where these athletes are defined through receiving centrally generated contracts with the IRFU. The Golfing Union of Ireland (GUI) also has a high-performance program that identifies and supports elite golfers in the country based on their performance and rankings at recognised events.

Elite athletes in Ireland have also been defined as those who possess exceptional physical and mental abilities and are capable of achieving success at the highest level of international competition, including Olympic and Paralympic Games, World Championships, European Championships, as well as collegiate, county and other major international events (Reardon et al. 2019). This varies slightly from the definition proposed by Swann and colleagues where he and his team more broadly categorised elite athletes using a scoring system that took into consideration factors such as; the athletes highest standard of performance, success of the athlete at their highest level, time at that level, competitiveness of the sport in the athletes' country and global competitiveness of the sport with their accompanied television audience (Swann et al. 2015). Reardon and colleagues through the International Olympic committee consensus statement on the mental health of elite athletes clearly define those "competing at professional, Olympic or collegiate levels" (Ljungqvist et al. 2009; Reardon et al. 2019).

1.2.2 Sport specific oral health risks

There are several oral health risks specific to individual sports which athletes should be aware of as highlighted recently (Anton et al. 2020). These include:

• Trauma to the mouth and teeth: Athletes who participate in contact sports such as football, hockey, and boxing are at a high risk of oral injuries, including broken or avulsed teeth, lacerations

to the lips and tongue, and jaw fractures (Cohenca et al. 2007). A study found of Barcelona football players found that 21.4% presented with dental trauma (Gay Escoda et al. 2011).

• Dry mouth: Athletes who engage in intense physical activity may experience dry mouth due to increased breathing through the mouth, decreased saliva production and dehydration (Budd et al. 2017). Dry mouth may lead to increased incidence of dental caries and, periodontal disease, and other oral health problems (Smith and Shaw 2003).

• Dental erosion: Athletes who consume sports drinks or energy drinks on a regular basis may be at higher risk of tooth erosion (Antunes et al. 2017). Many of these drinks are highly acidic, which can erode tooth enamel over time (Budd et al. 2017; Sirimaharaj et al. 2002).

• Dental appliances: Athletes who wear dental appliances, such as orthodontic braces or removable dental prosthesis, may be at a higher risk of oral injuries during sports and may need to take extra precautions to protect their teeth through use of appropriate protective oral appliances, such as custom mouthguards (Newsome et al. 2001).

• Vitamin and mineral deficiencies: Athletes who have restrictive diets or eat unbalanced diets may be at risk of vitamin and mineral deficiencies that can affect oral health (Meyer et al. 2007). Studies in children with severe Vitamin D deficiency have reported increased defective tooth mineralisation, resulting in enamel and dentine defects, and associated with higher prevalence of periodontitis and gingival inflammation (Botelho et al. 2022). However, one systematic review and meta-analysis concluded that there was “weak evidence supporting the association between vitamins and both gingival/periodontal disease and hard dental pathological processes” (Cagetti et al. 2020). However, this weak association may be down to the dosages of vitamins used in the trials they reviewed or the confounding factors such as existing varied treatment protocols camouflaging the effect of vitamins (Cagetti et al. 2020). Recent research has also suggested that suboptimal vitamin D level in children may be a significant risk factor for dental caries in Asian countries (Almoudi et al. 2019).

• Bruxism: Athletes who engage in repetitive and intense physical activity may be at risk of developing bruxism, which is the habit of grinding and clenching the teeth (Freiwald et al. 2021). Bruxism can cause tooth wear, jaw pain, and headaches (Freiwald et al. 2021). However, studies involving adolescent male and female athletes identified no difference in prevalence of signs and symptoms of TMJ dysfunction when compared to the general population (Weiler et al. 2010; Weiler et al. 2013).

1.2.3 Oral health and performance

Interest in oral health in sport has increased, in part due to a significant body of research now showing a high prevalence of oral disorders among athletes (Gallagher et al. 2021). As early as 2009, the International Olympics Committee (IOC) stated that “…further studies are required to

assess more accurately the oral health of the athlete population, and educational programmes should be expanded and targeted to those sports where the risks identified above influence athlete health…The IOC group encourages athletes to be provided with regular dental examinations" (Ljungqvist et al. 2009). As a result of this, and other research, according to the opinion of Kragt and co-workers, checking of oral health status should now be considered mandatory amongst Dutch athletes when assessing an athlete's eligibility to participate at an Olympic Games, with the purpose of increasing dental awareness and avoiding possible problems during competition (Kragt et al. 2019).

Previous studies have been published attempting to link oral health with an athletes' general physical condition, surmising that both dental caries and periodontal disease can act as infectious foci which may degenerate into cardiac problems due to the number of bacteria that are located at the gingival level and potentially access the bloodstream, affecting other regions of the body (de la Parte et al. 2021). However, robust evidence for this is lacking, with currently available literature only demonstrating a possible association between systemic conditions and endodontic pathosis (Khalighinejad et al. 2016). In that study they reviewed the available research and examined possible associations between endodontic pathosis and systemic diseases such as cardiovascular disease, diabetes mellitus, chronic liver disease, blood disorders and reduced bone mineral density. Khalighinejad and co-workers reported that from the sixteen case-control and retrospective cohort studies reviewed there "may be a moderate risk and correlation between some systemic diseases and endodontic pathosis" (Khalighinejad et al. 2016).

It was also proposed that many joint and muscle injuries were the consequence of dental foci and/or periapical infections as discussed in case reports and retrospective literature reviews. This is also considered controversial, with no evidence of cause and effect (Lorenzini et al. 2011; Moghimi et al. 2013). It has been proposed that this may theoretically lead to athletes suffering asthenia expressed as muscle fatigue, joint inflammation, joint pain, or tendon injuries with delayed or late recovery (de la Parte et al. 2021). It has also been proposed that the absence of teeth as a consequence of trauma or disease can lead to digestive disorders with a higher energy expenditure and slower digestion, potentially being a disadvantage in sports competition (de la Parte et al. 2021). However, this is largely based on literature in geriatric populations and is not be applicable to the younger age group of elite athletes (Walls and Steele 2004).

Craniomandibular disorders also tend to show a higher prevalence among athletes compared to non-athletes, where it is believed that habits such as bruxism may be stress induced as a result of competition or training (Freiwald et al. 2021). A 3-year prospective study by Lim of 266 females aged 18–34 years of age demonstrated that the development of temporomandibular joint disorder (TMD) may also cause head, neck and back muscle pain in a small number of athletes (6%) (Lim et al. 2010). Other research conducted by Weiler and co-workers compared young

female athletes and non-athletes and reported no increase in association or earlier onset of TMD development with participation in sport when other factors were controlled (Weiler et al. 2013). The same research group also published findings comparing male athletes and non-athletes and again found no association when comparing any association or earlier onset of TMD development with participation in sport (Weiler et al. 2010).

Research involving professional footballers and volleyball teams has also reported reduced sporting performance with oral health problems such as prevalence of caries, periodontal disease and facial pain (Gay Escoda et al. 2011 and De Souza et al. 2020).

A recent study involving one hundred and sixteen high- and elite-level Portuguese athletes from different sports were examined regarding their "dental relationships, teeth and periodontal health, the presence of parafunctional activities (bruxism) and current or past orthodontic treatment" and reported a high prevalence of oral disease which they stated "are not under control" (Cardoso et al. 2023).

There is currently a paucity literature linking oral health directly with athletic performance by way of physical ability to perform a particular task required of that sport. Recent studies tended to focus on the impact of oral health or trauma on performance (Ashley et al. 2015). One systematic review reported on four studies that demonstrated that between 5% and 18% of athletes reported negative impacts of oral health or trauma on performance (Ashley et al. 2015). They concluded that further research was indicated "to investigate the possible impact on performance using objective measures of performance" (Ashley et al. 2015). It was clear from these findings that it is difficult to establish cause and effect and directly link oral health status with athletic performance (Ashley et al. 2015; Needleman 2018; Cardoso et al. 2023).

A systematic review looking into the impact of oral health on physical fitness included eleven articles looking at outcome measures of physical fitness such as stabilometric tests to measure body balance, posturographic tests, aerobic tests, physical fitness tests (consisting of push-up, pull-up, sit-up, and running exercises), and hand grip test (Bramantoro et al. 2020). The included studies involved various non-athlete populations such as elderly, military, police and non-athletes (Bramantoro et al. 2020). They concluded that the oral conditions that strongly affected physical strength were malocclusion and periodontal disease (Bramantoro et al. 2020). They also found that some clinical parameters such as pocket probing depth, clinical attachment loss, and bleeding on probing, were related to physical strength (Brarmantoro et al. 2020). It was demonstrated that increasing clinical attachment loss was significantly associated with decreased handgrip strength (Oliveira et al. 2015).

Another study, not involving athletes, demonstrated a correlation between clinical parameters of periodontal disease and cardiorespiratory fitness (Eberhard et al. 2014). However, this study was

carried out on sedentary men aged between 45 and 65 which may not be applicable to the current study group (Eberhard et al. 2014).

There is clearly a need for further studies to objectively measure the relationship between oral health and athletic performance. This would be best investigated in longitudinal prospective studies across a number of countries to generate sufficient numbers of athletes across a range of sporting disciplines.

1.2.4 Olympic athletes and oral health

In contrast to the common perception that athletes have overall exceptional overall health, research has highlighted the reverse, including studies conducted at Olympic Games showing time and time again that the oral health of participating athletes is poor (Kragt et al. 2019; Needleman et al. 2013; Vougiouklakis et al. 2008). These findings have been highlighted by Needleman and co-workers where they highlighted that studies have consistently reported "poor oral health in elite athletes since the first report from the 1968 Olympic Games" (Needleman et al. 2013). These findings were consistent both across selected samples attending dental clinics at major competitions, such as the Olympic Games, and more representative sampling of teams (Kragt et al. 2019; Needleman et al. 2013; Vougiouklakis et al. 2008; Yang et al. 2011). More recent summer Olympic Games have demonstrated high dental treatment need as well as the high demand for provision of emergency dental care (Kragt et al. 2019; Needleman et al. 2013; Vougiouklakis et al. 2008; Yang et al. 2011). In addition to this, research conducted at the London Olympic games in 2012 found that over half of the athletes did not have a scheduled dental review or hygiene visit within a year of the event, and 8.7% had received no dental reviews at all (Needleman et al. 2013). These findings suggested that dental care was perceived as low priority among elite athletes and sporting organisations as well as identifying potential barriers to accessing services for athletes from lower socio-economic backgrounds (Needleman et al. 2013). A UK study showed a trend towards the oral health in athletes being similar to that of non-athletes from lower socioeconomic backgrounds and disadvantaged communities (Gallagher et al. 2020). However, this study did not comment on the socioeconomic background of the athletes that participated in the study (Gallagher et al. 2020). A study undertaken by Dutch researchers also reported that the prevalence of oral diseases did not appear to be connected with socio-economic background or geographical location, since both athletes from developing and industrialised countries presented with similarly poor levels of oral health (Kragt et al. 2019).

1.2.5 Sports Dentistry

With the advancement of sports medicine in striving to achieve and maintain ever greater athletic performance, sports dentistry is seen to play a significant role (Stamos et al. 2020). This consensus

statement advocated the need to integrate sports dentistry into sports medicine (Stamos et al. 2020). They proposed that sports dentists could be valuable members of the sports medical team "and the joint efforts to provide better prevention and health to athletes will benefit the overall medical assessment of athletes' health" (Stamos et al. 2020). They, like previous researchers, suggested that dental screening should be part of the standard medical screens of athletes (Gallagher et al. 2021; Kragt et al. 2019; Needleman et al. 2013; Stamos et al. 2013). Sports dentistry has been labelled as a specific branch of sports medicine in the prevention, diagnosis and management of dental injuries and oral diseases associated with sports and exercise (Gallagher et al. 2021; Kragt et al. 2019; Stamos et al. 2020).

Dental disorders such as non-carious cervical lesions and even dental caries can be caused by factors in sports such as overtraining, dehydration, unfavourable diet, bruxism and poor oral hygiene, based on the opinions of the authors of a recent literature review (Anton et al. 2020). It is also surmised that swimmers are particularly vulnerable to dental erosion as a result of the exposure to acidic pool environments due to the acidity of chlorinated water. This however is anecdotal as it is difficult to establish cause and effect (Cardoso et al. 2020). Moreover, even "in properly maintained gas-chlorinated pools, dental stains develop from the interaction between saliva and chemicals used for pool water disinfection (when contact are >6 h/week) predominantly on the maxillary and mandibular incisors" (Cardoso et al. 2020). These dental stains have demonstrated that the length of time that teeth are in contact with chlorinated water is key and possibly reflect the potential for erosive damage to teeth (Escartin et al. 2000).

The World Dental Federation (FDI) has also raised awareness in relation to the indirect "doping" effects of common dental prescriptions such as opioid medications. It is known that such pharmaceuticals prescribed can be converted into prohibited substances when metabolised, but this can vary by country and sporting governing body (Heuberger and Cohen 2019). Avoidance of use of these pharmaceutical substances for example could lead to unnecessary pain and further functional degeneration or avoidance of utilising necessary services and treatment (Hainline et al. 2018).

The FDI have:

- Emphasised the significance of personalised mouthguards, shock-absorbing materials, and appropriate use times.
- Encouraged preventative actions for the preservation of healthy oral tissues.
- Informed dentists about the metabolism of prescription medications that may be in violation of World Anti-Doping Agency (WADA) laws through publication of guidance and articles.

• Explained the significance of an athlete's oral health state to their performance, as well as the appearance of oral lesions caused by conditions in sport such as prolonged dry mouth as a result of mouth breathing and lack of adequate hydration.
• Emphasised the significance of the link between an athlete's oral and overall health.
• Emphasised the importance of eating a well-balanced diet for optimal dental health (FDIWD 2017).

1.2.6 Nutrition and Elite athletes

Dietary assessment amongst elite athletes is challenging for several reasons, including the burden and difficulty of accurately reporting all the foods and beverages consumed, the expense and resources required to undertake dietary analysis and allow sufficient time allocation for athlete feedback and behaviour change (Capling et al. 2019). As a result, dietary assessment may be conducted infrequently or not at all, making it difficult for sports nutritionists and researchers to identify athletes requiring dietary support or to evaluate the effectiveness of nutrition interventions (Capling et al. 2019).

Researchers have therefore developed and subsequently evaluated an athlete specific-diet index in order to mitigate these problems. Evaluation of the developed index in an Australian elite athlete population was proven to assist in the rapid screening of athletes, direct accredited sports nutritionists' attention to specific areas of dietary concern, and tailor nutrition intervention strategies (Capling et al. 2020). They found that athletes training fewer hours (0-11 h/week) scored higher on dietary habit sub-scores compared with athletes training longer (over 12 h/week) (Capling et al. 2020). A higher score indicated better compliance with dietary recommendations (Capling et al. 2020).

The same research group recently assessed this tool for both reliability and validity, and "demonstrated good reliability in elite athletes" (Capling et al. 2021). This was undertaken through comparison with a reference method of dietary assessment, in this case a 4-D estimated food record (Capling et al. 2021). Its use in research outside of that group is currently lacking as it was published and validated concomitantly during the period where existing relevant research had already begun and researchers felt they could not adapt their existing protocol to include it (Schneider, Sasaki and da Costa 2023). Those researchers were unable to validate and evaluate the athlete diet index as they had already submitted a protocol for their research which was already underway for two other diet indices, and the Athlete Diet Index was yet to be published (Schneider, Sasaki and da Costa 2023). In the future research protocols may opt to include the index as more field research is initiated following lifting of restrictions following the Covid 19 pandemic.

Dietary assessment in this niche group was further complicated as standard dietary assessments were applied (Schneider, Sasaki and da Costa 2023). Pitfalls of this methodology related to athlete-specific issues involved a variable energy intake, periodised energy expenditure, frequent eating habits, and use of sports and dietary supplements which can complicate dietary assessment (Magkos and Yannakoulia, 2003). They concluded that care should be taken to ensure that diet monitoring accurately reflects usual food consumption during the period of interest as under-reporting of habitual energy intake is widespread among athletes (Magkos and Yannakoulia 2003). Furthermore, it is imperative to appreciate that dietary requirements and nutritionist prescription can vary considerably between different sporting disciplines as well as energy requirements and recommended intake for athletes within the same sporting team and disciplines to support different roles or goals (Werner et al. 2022). A common theme amongst elite athlete dietary prescription appeared to be a high intake of carbohydrates for replenishing glycogen post training and competition. (Capling et al. 2020).

1.2.7 Elite athlete dietary programme adherence

Adherence to prescribed sports performance diet plans is seen to be a crucial factor in achieving optimal performance among elite athletes (Maughan et al 2011). Nutrition is required to fuel the body for optimal performance and recovery. This view has long been supported by the evidence-based positions of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine (American Dietetic Association 2000; Beck et al. 2015; Rodriguez et al. 2009). Researchers have acknowledged that no single diet is universally recommended for athletes and therefore appropriate prescription relative to sporting discipline and necessary performance is indicated (Kaufman et al. 2023). Studies have shown that adherence to these performance diets is often poor (Bentley et al. 2021). Factors which contributed to poor adherence included lack of knowledge about the diet, lack of support from coaches and team dietitians, and difficulty in maintaining the prescribed diet while traveling or competing abroad (Bentley et al. 2020). Other studies have shown that athletes who had a greater understanding of the purpose and benefits of a diet plan were more likely to adhere to it (Bentley et al. 2021). In this example, Bentley and co-workers used the capability, opportunity, and motivation behaviour model and the theoretical domains framework to conduct focus group discussion with athletes and assess athlete adherence to prescribed diets (Bentley et al. 2021). This approach appears to have stemmed from earlier developments in behavioural change frameworks used to discourage tobacco usage and reduce obesity (Michie et al. 2011). Athletes who had positive attitudes towards their diet and received support from coaches and team dietitians were more likely to adhere to the diet, however, the authors do not quantify the effects (Bentley et al. 2021).

In addition, athletes who had the autonomy to make their own food choices, and had access to a variety of healthy food options, were more likely to adhere to a prescribed diet (Michie et al. 2011). It's important to note that poor adherence to a sports performance diet can have negative effects on both an athlete's performance and health (Maughan and Shirreffs 2012). However, this effect is also difficult to quantify (Bentley et al. 2019). Studies that assessed dietary adherence relative to performance tended to use measures of performance which were heavily influenced by body composition, such as, isometric handgrip test and height of jump by counter-jump on contact platform (Martínez-Rodríguez et al. 2021). Thus, researchers believed the negative impact on body composition through lack of adherence to the prescribed diet resulted in negative impacts on measures used to assess performance (Martínez-Rodríguez et al. 2021). Therefore, it is seen as crucial for coaches, athletes and sports nutritionists to work together to develop personalised, realistic and sustainable sports performance diets that meet the specific needs of the athlete and which can be adhered to in the long-term (Carter et al. 2022).

1.2.8 Nutrition and dietary supplementation of elite athletes

Nutritional supplement consumption is highly prevalent among athletes, with some studies reporting up to 90% of athletes using supplements (de Silva et al. 2010). However, a more recent study evaluating the prevalence and patterns of dietary supplement use in elite Spanish athletes demonstrated that just 64% of the 337 athletes surveyed used dietary supplements (Baltazar-Martins, et al. 2019). It is clear, that there were multiple factors which influenced an athlete's decision to take nutritional supplements, such type of sport, availability of supplements, nutrition and anti-doping education, religious and cultural beliefs (Baltazar-Martins et al. 2019). Although there are a considerable number of supplements commercially available, only a few are supported by scientific evidence for positive health and performance benefits, and instead are based on what can be marketed to the general population (Maughan et al. 2011).
Furthermore, some studies have suggested that an athlete's choices in nutritional supplements selection were likely not based on scientific evidence, but merely the promotional claims of the product (Sousa et al. 2013). Moreover, contamination of nutritional supplements is a growing concern as it can result in inadvertent doping and health issues from side effects or interactions with other prescription medications (Geyer et al. 2008). Researchers used mass spectrometric methods to analyse nutritional supplements, during their study they showed contamination with prohibited stimulants as ephedrines, caffeine, methylenedioxymetamphetamie and sibutramine, and anabolic steroids (Geyer et al. 2008). Characteristics that are linked to nutritional supplement usage tend to relate to the type of sport, age and level of competition (Erdman et al 2006; Erdman et al. 2007; Froiland et al. 2004). Additionally, healthier behaviours and food choices tended to be positively associated with nutritional supplement usage (Sousa et al. 2016).

Research conducted on Portuguese elite athletes analysed the differences between sociodemographic and sporting characteristics and supplement usage (Sousa et al. 2016). In that study, all athletes, regardless of discipline, or team versus individual, believed that the use of nutritional supplements was "mandatory for achieving maximal performance" (Sousa et al. 2016). Dietz and co-workers reported that young German athletes aiming to become an Olympic or World Champion had 3.7 times greater odds to be a nutritional supplement user (Dietz et al. 2014). Athletes from a variety of sporting disciplines, as reported in a study of Austrian athletes found that they believed that heavy training loads increased a need for supplementation (Dascombe et al. 2010).

Furthermore, supplement usage tended to be linked to dietary adherence, whereby individual sports athletes showed a greater prevalence of supplementation usage, which was believed to be due to individual sporting athletes having greater belief that their performance could positively influence the outcome of their sport, than athletes participating in team-based sports (Giannopoulou et al. 2013). Moreover, there appeared to be a negative association between the parental level of education and the athlete's supplement usage (Sousa et al. 2016). Studies concluded that athletes who used supplements appeared to be those that not only made healthier food choices, but made more sport-conscious decisions regarding food intake (Sousa et al. 2016). Self-reported justification by athletes found that sports nutrition supplement use was related primarily to achieving improved performance (Sousa et al. 2016).

1.2.9 Athlete's perspective

Athlete adherence to dietary recommendations was considered challenging, with suboptimal carbohydrate and micronutrient intake frequently reported amongst athlete populations (Bentley et al. 2021). This was problematic as an inadequate macronutrient and micronutrient intake may impair training adaptations, reduce competition performance and increase the risks of injury and illness (Close et al. 2019). Research conducted on military personnel undergoing basic combat training demonstrated a higher incidence of stress fractures in soldiers with dietary deficiencies, in particular deficiencies in foods containing vitamin D and calcium (Moran et al. 2012).

Attempts have been made to improve athletes' dietary behaviour through the delivery of educational workshops to enhance knowledge and this approach tends to be the dominant intervention (Bentley, Mitchell, and Blackhouse 2020). A recent systematic review conducted by Bentley and co-workers identified that 15 of the 16 eligible sports nutrition interventions used "Education" as their main strategy to change athletes' dietary behaviours (Bentley, Mitchell, and Blackhouse 2020). This appeared to be the preferred strategy utilised with current behaviour change strategies (Bentley, Mitchell, and Blackhouse 2020). One issue with this method was that very little consideration was given by researchers to evaluating behavioural change. Evaluating

behavioural change is important for increasing understanding on how and why such interventions work. Contrary to this, research has demonstrated that increased knowledge does not always result in improved dietary practices, and therefore education alone was considered insufficient to change or sustain behavioural change and therefore dietary adherence was considered multifactorial (Bentley et al. 2021). Qualitative research conducted by Bentley and co-workers revealed a range of factors which influenced an athletes' adherence to nutritional guidelines, including "their capability, opportunity and motivation" (Bentley et al. 2021). The factors that influenced an athletes' adherence were: (1) food planning skills, (2) a desire to enhance performance, (3) an emotional connection with food and performance, and (4) a positive working relationship with a sports nutritionist (Bentley et al. 2021). Interestingly, athletes also reported the importance of appearance which conformed to an athletic persona and the social and environmental pressures on body composition in relation to social media and perceived desirable appearance (Sharples et al. 2021). This was a qualitative study using in person individual interviews from either a professional rugby union Super Rugby franchise or their development squads in New Zealand (Sharples et al. 2021). In this study participants undertook recorded in-person interviews which were subsequently transcribed and coded to be evaluated by the research team (Sharples et al. 2021).

The same research group also reported that developing younger rugby union players placed greater emphasis on dietary adherence for improved appearance than more mature, well established rugby union players, where it was reported that 53% (16/30) of participants surveyed worried about their skinfold measurements which was indicative of worries about their appearance (Sharples et al. 2021). Additionally, athletes highlighted the importance of emotions on nutritional adherence and ongoing research has since aimed on focusing on the importance of a holistic-developmental approach to support an athlete's wellbeing (Bentley et al. 2021).

1.2.10 Nutritionist perspective

Sports nutritionists have identified several perceived barriers and enablers to an athletes' nutritional adherence in a high-performance setting (Carter et al. 2021). Firstly, sports nutritionists perceived those athletes that did not adhere to the nutritional plan "lacked the memory, attention, decision-making, and organisational skills required for the food planning and preparation necessary for nutritional adherence" (Bentley et al. 2019). Sports nutritionists interviewed in by Bentley and co-workers reflected that the athlete would bring a 'dependency mindset' to the performance nutrition service and insist they be told what to do regarding their dietary behaviour rather than working through a decision-making process constructively to develop their own food planning and preparation skills (Bentley et al. 2019). Certainly, it appeared that nutritionists believed that the main barrier to dietary adherence in that population was that

athletes had an inability to regulate and take personal responsibility for their own dietary behaviour (Bentley et al. 2019). Additionally, it has been reported that the performance culture of sport reinforced and stimulated nutritional ideologies based on performance rather than nutritional recommendations for health (Sandgren et al. 2022). Whilst nutritionists believed that a positive tangible improvement in performance favoured adherence to nutritional advice, it was reported that an improvement in health was not a sufficient motivator for dietary adherence in athletes based on structured athlete interviews (Bentley et al. 2019). This idea of performance accountability tended to be more relevant in individual sports such as boxing and cycling than team-based sports, as individual athletes' perceptions of meaningfully influencing the outcome of competitions in team-based sports were lower than for individual sports (Bentley et al. 2019). Ultimately, it appeared that the nutritionist's predominant role was reinforcing performance rather than health. Moreover, there was a perception among nutritionists that their colleagues such as sports performance coaches and chefs might have been a barrier to nutritional adherence and may even contradict the advice given by nutritionists where some chefs for example would try to gain favour with athletes by providing additional calorifically dense but nutritionally poor "treats" such as chocolate cake (Bentley et al. 2019).

Unfortunately, nutritionists tended to report very little influence on the provision of food and its service within the training environment. For example, several sports nutritionists have shared their experiences on needing to negotiate environments that were shaped by local councils and/or event managers (Bentley et al. 2019). Where in such contexts, "multi-stakeholder use, profit, and perceived customer satisfaction appear to drive food provision, rather than athletes' dietary requirements" (Bentley et al. 2019). It is also important to note that nutritionist time with athletes can also be extremely limited given athletes' training and competition commitments, where one qualitative study reported, sometimes as little as "one day per week" (Carter et al. 2021). It has been reported in a systematic review by Tan and co-workers that athletes have limited contact time for nutrition education with most interventions being less than 5 hours in duration (Tam et al. 2019).

1.2.11 Elite athletes and eating disorders

Eating disorders are a common issue among elite athletes, particularly those in sports that place a strong emphasis on weight and body shape (Lichtenstein et al. 2022). These sports include gymnastics, diving, figure skating, and wrestling. A recent systematic review and meta-analysis reported a prevalence of eating disorders in the general population of 1.89% in Western countries (Qian et al. 2021). However, a recent scoping review of eating disorders in male athletes reported a prevalence of up to 32.5% (Karrer et al. 2020). There is also a body of evidence demonstrating significantly greater prevalence of eating disorders among female elite athletes when compared

with the general population (Sundgot-Bergen 1993). In that study, 193 elite female athletes were interviewed and clinically examined (Sundgot-Bergen 1993). The most common eating disorders among female elite athletes were anorexia nervosa and bulimia nervosa, where a significantly higher number of athletes (18%) than controls (5%) demonstrated eating disorders (Sundgot-Bergen 1993). Anorexia nervosa is characterised by a fear of gaining weight, distorted body image, and restriction of food intake (Phillipou et al. 2018). Athletes with anorexia may excessively restrict their food intake, use excessive exercise as a means of weight control, and have a distorted perception of their own body weight and shape (Sundgot-Borgen and Torstveit 2004). Bulimia nervosa is characterised by recurrent episodes of binge eating followed by compensatory behaviours such as purging, fasting, or excessive exercise (Kaye 2008). Athletes with bulimia may engage in binge eating and then use purging behaviours such as self-induced vomiting or laxative abuse to control their weight (Presskreischer et al. 2023). The prevalence of eating disorders among elite athletes varied depending on the sport and level of competition, but studies have found that the incidence is higher among athletes compared to the general population. (Lichtenstein et al. 2022). This study invited participants form previous research by Lichtenstein and co-workers in 2021, which involved 417 male and female Danish national team elite athletes (Lichtenstein et al. 2021). From those who were invited to participate, twenty of a representative sample of 28 (25 female, 3 male) athletes had a confirmed eating disorder according to Eating Disorder Examination Questionnaire criteria (Lichtenstein et al. 2022).

Research also described how the prevalence of eating disorders increased significantly in the general population from 3.5% in the time period 2000-2006 to 7.8% in the period 2013-2018 (Galmiche et al. 2019). One study examined the prevalence of self-reported eating disorders amongst the entire male and female Norwegian elite athlete population, (1620: 960 males, 660 females), showed a prevalence of 20% in females compared with just 8% in males (Sundgot-Borgen and Torstveit 2004). There was a high response rate of 78% amongst athletes and they were matched to a sample from the general population for comparison (Sundgot-Borgen and Torstveit 2004). It is important to note that eating disorders among athletes can have severe and long-lasting effects on their physical, mental and oral health, and can also negatively impact their athletic performance (Kisley et al. 2015). Early detection and intervention were crucial to help athletes overcome eating disorders and return to healthy training and competition (El Goch et al. 2013).

1.2.12 Sport Modalities (individual vs team)

More recently, research conducted by de la Parte and co-workers has evaluated the oral health and oral health habits of elite athletes according to practiced sports modality (de la Parte et al. 2021). They demonstrated that there was no significant difference in Oral Health Impact Profile-

14 (OHIP-14) scores according to sport type. This may be in part due to the OHIP-14 tool not being sensitive enough to capture the full range of low-impact problems or mild oral health issues (Allen 2003; Hebling and Pereira 2007). The OHIP may not have been able to differentiate among people who have different levels of minor issues as it is designed to capture more serious oral health problems (Hebling and Pereira 2007). As a result, many respondents might end up with similar, low OHIP scores, which may limit the tool's usefulness when trying to distinguish between various low-impact interventions or preventive strategies (Allen and Locker 2002; Slade and Spencer 1994). This has also been demonstrated to be the case in one study which attempted to predict response rates and then compare OHIP-14 scores from a general population in the United Kingdom with the general population of Australia, and reported an accuracy over 98%. However, no data on sensitivity or specificity of findings were provided (Nuttall et al. 2006). In the only study directly comparing the oral health of different sport modalities team sport athletes displayed a greater number of teeth and a greater DMFT index compared to the individual sport athletes (de la Parte et al. 2021). However, no differences were identified when comparing the OHIP-14 scores of the different types of sports. Thus “this self-perception was not completely in accordance with the results achieved through clinical examination” (de la Parte et al. 2021). In that study, no distinction was made between sexes, the nutritional intake of the participants was not analysed and there was no control group (de la Parte et al. 2021). Researchers proposed that it may be due to the fact that athletes who participated in individual sports and train individually often decide when they visit dentist without specific and institutionalised guidelines, and many factors, such as fear, training schedules, geographical limitations and lack of economic support, may negatively affect their awareness of oral health (Bryant et al. 2011; Gallagher et al. 2019; Needleman et al. 2015).

1.2.13 Amateur athlete’s vs elite athletes’ oral health comparison

A retrospective cross-sectional study conducted in Germany directly compared the oral health status of amateur and competitive athletes (Merle et al. 2022). Merle and co-workers used similar parameters to previous research conducted by Needleman in 2013 and Gallagher in 2020 when recording oral disease prevalence such as DMFT, BEWE, periodontal screening indices and oral health behaviour and attitudes questionnaires (Needleman et al. 2013, Gallagher et al. 2020). Merle and colleagues reported increased oral disease prevalence in competitive athletes when compared to amateur athletes (Merle et al. 2022). From their findings they reported significantly less decayed teeth, lower plaque indices, more favourable periodontal index scores and reduced incidence of temporomandibular disorders in amateur athletes (Merle et al. 2022). However, there was similar oral health behaviour and attitudes in both group and the authors concluded that there may indeed be an increased dental care need in competitive sports potentially as a

result of dietary demands, training intensity and use of dietary supplementation (Merle et al. 2022).

1.2.14 Armed forces oral health

Interestingly, a study conducted by Finnish researchers into the association between dental caries, physical activity and physical fitness, among male conscripts found that regularly exercising conscripts had a reduced need for dental restorative treatment than those reporting no physical activity (Huttunen et al. 2022). They also reported that the proportion of participants with sound dentitions steadily increased with an increase in physical activity. However, they proposed that these findings were correlated with a lower prevalence of smoking and low use of alcohol and energy drinks in those who exercised frequently.

On the other hand, a study into the oral health of Dutch armed forces personnel found an association between ranking of military personnel and oral health status (van Klink 2022). Here they found that "the lowest ranked military personnel are more frequently classified as dentally unfit for deployment than officers", based on DMFT, Dutch Periodontal Screening Index and Simplified Oral Hygiene Index (van Klink 2022). In addition to this, the lower military rankings were also associated with lower education levels and lower socio-economic backgrounds which also may have been more relevant associations (van Klink 2022).

1.2.15 Oral health promotion

Research to date has highlighted a clear issue with oral health in athletes, with steps having been taken to target oral health education in this vulnerable group. The International Olympics Committee state that "…further studies are required to assess more accurately the oral health of the athlete population, and educational programmes should be expanded and targeted to those sports where the risks identified above influence athlete health…The IOC group encourages athletes to be provided with regular dental examinations" (Ljungqvist et al. 2009). However, no further guidance or recommendation in relation to oral health have been published by this organisation.

Strategies for oral health promotion and education have already been implemented for the Great British and Northern Irish Olympic athletes through the Eastman Dental Institute in London (Needleman et al. 2016). These have included the introduction of periodic oral health screening, universal application of high-risk prevention and risk mitigation strategies, and integration of oral health promotion within the overall care of the athlete (Needleman et al. 2016). Further research following its implementation will be necessary to evaluate its success on disease prevalence in the athletic community it serves as well as evaluating potential benefits such as sport performance and quality of life. Government led oral health promotion, education and delivery specific to

athletes on this scale appear be unique to the United Kingdom (UK) likely owing to the provision of the National Health Service (NHS) and current available infrastructure (Gray et al. 2019). Although more recent studies such as one conducted on Dutch athletes have stressed the need for regular screening of oral health incorporated "into the general preventative health care of elite athletes", where they found that 43% of athletes studied demonstrated oral findings necessitating dental care (Kragt et al. 2019).

It is also imperative to recognise clinicians' attitudes to oral health education in these circumstances. Research has shown that knowledge on how and what to deliver is not the only important factor in achieving successful positive change, but also maintaining sufficient motivation to be able to deliver and communicate these messages effectively to patients. Research conducted by Barnes and co-workers has demonstrated that clinicians' attitudes to providing continued oral health education depended on a patient's adherence and compliance with such advice (Barnes et al. 2022). They also demonstrated the importance of good interpersonal relationships between the clinician and patients in delivering oral health education as well as the patients themselves being willing to implement appropriate change (Barnes et al. 2022).

Elite athletes often commence their careers when they join youth development squads and dental professionals should enable them at this early age to take joint ownership of their oral health (Ashley et al. 2015). A recent consensus report based on expert opinion and three systematic reviews stated that the most important behavioural factor affecting both dental caries and periodontal diseases was routinely performed, effective oral hygiene with fluoride application through regular professional examination and reinforced professional advice (Jepsen et al. 2017). Jepsen and co-workers concluded that prevention and control of dental caries and periodontal diseases and the prevention of tooth loss is a lifelong commitment "employing population- and individual-based interventions" (Jepsen et al. 2017). This idea has led to research groups advocating for specific roles such as sports dentists to be integrated into the multidisciplinary care and training of athletes (Cardoso et al. 2023; Gallagher et al. 2021; Gallagher 2023).

A feasibility study, based on contemporary behaviour change strategies designed with input from athletes was conducted by Gallagher and co-workers (Gallagher et al. 2019). The strategies employed were developed from what was considered the dominant approach for understanding health behaviour, the Capability, opportunity, motivation behaviour change (COM-B) model (Michie et al. 2011). They implemented these strategies and services within three different high-performance sport environments and found that they were associated with an increase in athlete oral health knowledge, enhanced oral health behaviours and a reduction in self-reported performance impacts (Gallagher et al. 2020). The study reported that mean oral health knowledge scores increased from 6 to 8, the use of prescription fluoridated toothpaste more than once a day,

increased from 8% at baseline to 45%, and a significant reduction on Oslo Trauma Research Centre scores from baseline was observed (Gallagher et al. 2020).

It was clear that all members of an integrated athlete support team had key roles to play in health promotion, injury prevention and sport performance. Later work by the same authors proposed guidance as to the potential requirements and role of a sport's specific dental service (Gallagher et al. 2021). Researchers advocated for the provision of custom-made mouthguard to provide protection against orofacial trauma, and potentially, concussion. Moreover, oral health screening was recommended during athlete pre-season preparation with dentists being integrated members of the sports team (Cardoso et al. 2023; Gallagher et al. 2021; Wisniewski et al. 2022).

1.3 Epidemiological Measures

1.3.1 Oral health

Oral health is not merely defined by the absence of disease but was defined by the FDI as "multifaceted and includes the ability to speak, smile, smell, taste, touch, chew, swallow, and convey a range of emotions through facial expressions with confidence and without pain, discomfort, and disease of the craniofacial complex" (Glick et al. 2016). The FDI represents over a million dentists through more than 200 national dental associations in over 130 counties. The FDI represents dentistry at the World Health Organisation (WHO) and is an important member of the World Health Professions Alliance and the Supporters Consultation Group of the Non-Communicable Disease Alliance (Glick et al. 2016). Adoption of the FDI definition of oral health has led to several benefits. The new definition echoes that used by the WHO and national dental associations worldwide, and was therefore seen as an evolution of existing definitions. It has encouraged dentistry from treating disease to a more modern approach of disease prevention in providing oral health (Innes et al. 2019). It used language that resonated with healthcare professionals in providing service provision but also provides a sound framework for researchers to collaborate and communicate effectively (CSDH 2008). Importantly, it raised awareness of the different dimensions of oral health and highlighted that oral health does not occur in isolation but is embedded in the wider framework of overall health (Glick et al. 2016). The creation of this definition and its acceptance is intended to be used by all stakeholders and builds on the WHO's Commission on Social Determinants of Health Report (CSDH 2008).

1.3.2 Evaluation of oral health

Disease presence is measured through application of appropriate indices (Young et al. 2008). Validation of clinical indices in dentistry ensures the accuracy and reliability of what they are intended to measure (Young et al. 2008). This is crucially important as indices are often used clinically and in research to assess the presence and severity of diseases, the impact of a particular

intervention, or to understand the health status of a given population (Ramanarayanan et al. 2020). There are several methods of validating clinical indices including content validity, criterion validity, construct validity, reliability testing, and assessing sensitivity and specificity (Anastassiadou et al. 2002). In research, the validation of clinical indices is important as if gives researchers confidence in the results and conclusions drawn from studies. If an unvalidated index is employed, the results may be misleading, inaccurate or unreliable. The use of validated indices allows for comparability of results across different studies and populations, which is key to be able to generalise research findings and apply them in different contexts (de Souza et al. 2014; Ramanarayanan et al. 2020).

Validation of indices should be carried out periodically, in particular when used in different populations or settings, to ensure they remain accurate and reliable (Young et al. 2008). Oral health can be objectively evaluated through validated dental indices as well as subjectively through oral health questionnaires (Palma et al. 2017). Much of the oral health research on elite athletes has focused on the use of validated oral health indices so that collaboration and effective communication can be achieved amongst different researchers in this newly developed field of sports dentistry (Bryant et al. 2011; Kragt et al. 2019; Needleman et al. 2013).

1.3.3 Recording of dental caries

The World Health Organisation (WHO) has long recommended that epidemiological data regarding dental health and morbidity be of primary importance (Aggeryd 1983). One such commonly used index to determine caries prevalence has been the DMFT (Becker et al. 2007). The D component is for recording untreated caries, M is for missing teeth due to caries, and F is for the presence of restoration (dental restorations), and T means index per tooth as opposed to tooth surface (Becker et al. 2007). This index is widely used in epidemiological data collection as it is based on a clinical examination alone and does not require the use of radiographs (Gordon et al. 2018; Hopcraft and Morgan 2005). This is important as the use of radiographs to detect proximal caries is not appropriate for epidemiological research (van Dommelen and Schuller 2016). As a result, the DMFT has been criticised for under reporting the extent of dental caries and number of lesions in a tooth (Rai et al. 2023). It is therefore likely that using the DMFT underestimates the need for restorative intervention (Becker et al. 2007).

Research conducted by Bloemendal and co-workers demonstrated that caries prevalence was considerably higher when clinical and radiographic examination were used rather than clinical examination alone (Bloemendal et al. 2004). They concluded that despite this finding, they demonstrated that clinical examination alone with DMFT was still sufficient to establish trends but further research was necessary to obtain a valid conversion factor for relevant patient categories (Bloemendal et al. 2004). One study which was quoted as part of that systematic

review demonstrated differences of just five surfaces presenting with carious lesions following clinical examination alone, versus 5.4 carious surfaces following the addition of radiographic examination when enamel lesions were excluded (de Vries et al. 1990). However, despite the small diagnostic benefits when diagnosing the number of carious lesions into dentine in a population at a certain point in time, they concluded that radiographic examinations did have additional value (Bloemendal et al. 2004). These criticisms of the use of DMFT led to the development of a new index developed by an expert panel in Dundee in 2002, the International Caries Detection and Assessment System (ICDAS) (Gugani et al. 2011).

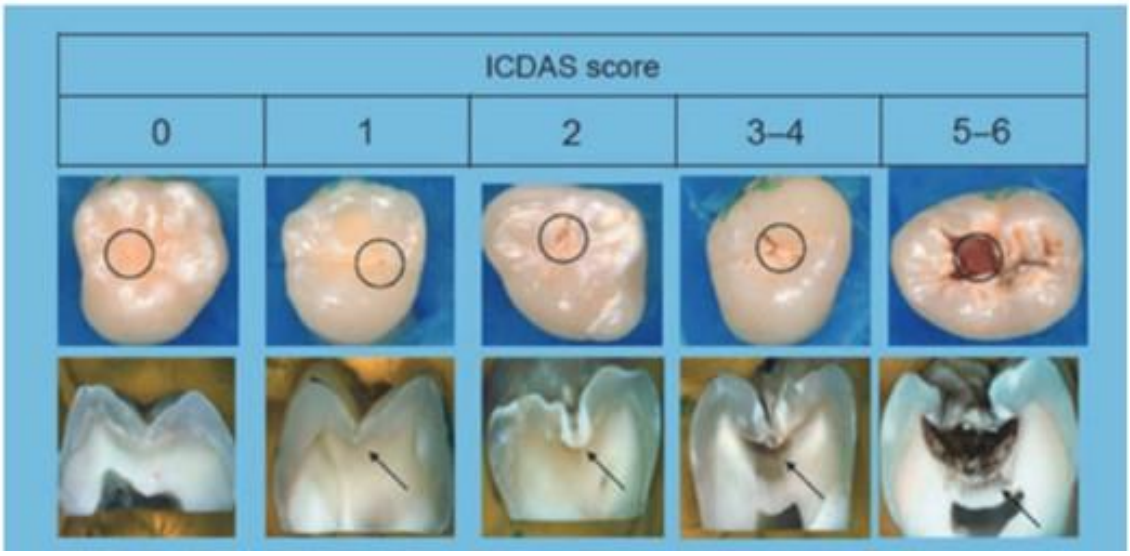


Figure 1.1 ICDAS codes based on histological extent of lesions, stages of caries continuum (Pitts and Ekstrand 2013).

Key to two-digit codes in the ICDAS II scoring system	
Restoration and sealant codes	**Caries codes**
0 = Not sealed or restored	0 = South tooth surface
1 = Sealant, partial	1 = First visual change in enamel
2 = Sealant, full	2 = Distinct visual change in enamel
3 = Tooth-coloured restoration	3 = Enamel breakdown, no dentine visible
4 = Amalgam restoration	4 = Dentinal shadow (not cavitated into dentine)
5 = Stainless steel crown	5 = Distinct cavity with visible dentine
6 = Porcelain, gold, PFM crown or veneer	6 = Extensive distinct cavity with visible dentine
7 = Lost or broken restoration	
8 = Temporary restoration	**Missing teeth**
	97 = Extracted due to caries
	98 = Missing for other reason
	99 = Unerupted

Table 1.1 Table demonstrating key to two-digit codes used in the ICDAS II scoring system.

A further conference held in Boston, USA in 2004, decided that the original scores of 3 (shadowed lesion) and 4 (enamel cavitation) in the ICDAS scoring system should be interchanged; attendees agreed that as shadowed lesions histologically were deeper than enamel lesions, this was more appropriate, resulting in the ICDAS II (Ekstrand et al. 2018). It was concluded that "ICDAS II is better than digital radiographs in detecting carious lesions confined to enamel, and both are equally effective in the detection of dentinal carious lesions" based on an evaluation on 249 primary molars in 35 children by two independent calibrated examiners (Bhumireddy et al. 2018). A systematic review conducted in 2018 looked at the reproducibility and accuracy of the ICDAS examination (Ekstrand et al. 2018). They reported that ICDAS I showed moderate to substantial reproducibility and accuracy for both intra- and inter- examiner reliability (weighted Kappa coefficients of 0.7 and 0.65 respectively) based on a meta-analysis assessing coronal caries lesions, and the use of systems associated with the ICDAS for activity assessment of coronal caries lesions (Ekstrand et al. 2018). Moreover, by establishing an agreed caries threshold score through the use of ICDAS, new findings, can be compared directly with existing research that used DMFT, for example an ICDAS score of 4 or more is equivalent to the presence of decay in a tooth when using the DMFT scoring system (Mendes et al. 2010). However, caution was advised as different indices can impact the conclusions drawn from such data, with ICDAS having higher specificity (69.3-100% versus 69.4%) and sensitivity (69.8-73.2% versus 55-98.7%) when reporting caries

(Coelho 2020). Where according to Potlia and co-workers, the ICDAS gives more information than DMFT about the caries state, stage, depth of penetration, restoration types, and their conditions (Potlia et al. 2016).

1.3.4 Recording of dental erosion

Smith and Knight originally developed a method of scoring erosive tooth wear in 1984 (Smith and Knight 1984). They classified tooth wear into four categories: no wear, incipient wear, moderate wear and severe wear, based on visual examination alone (Smith and Knight 1984). However, this index did not describe the aetiology of tooth wear observed and was considered non-specific as it only accounted for depth of wear rather than describe the aetiology (Attin and Wegehaupt 2014; Dixon et al. 2012).

An improved scoring system was developed to simplify the recording of erosive wear by general practitioners which is considered simpler, with higher sensitivity and specificity for tooth wear caused by erosion (Dixon et al. 2012; Lee et al. 2011; Ramesh et al. 2022). They developed the Basic Erosive Wear Examination (BEWE) to also allow comparison with other more discriminative indices such as the Tooth Wear Index (Marro et al. 2018). The tooth wear index (TWI) is not as sensitive to early signs of wear, tends to be more detailed, and therefore taking longer to carry out, and it focuses on specific and detailed aspects, sometimes overlooking the broader cumulative perspective (Donachie and Walls 1996). The BEWE has been applauded for its high specificity, over 90%, in erosive wear diagnosis but suffers with low sensitivity (48.6%) in individuals with moderate to severe wear and therefore results should be interpreted with caution when using it to prescribe treatment or describe prevalence based on severity of disease (Dixon et al. 2012). Recent research has demonstrated improved agreement when comparing a simplified tooth wear index with the BEWE (Ramesh et al. 2022). Ramesh and co-workers concluded that the agreement between the indices was high, where the agreement “was 0.745 (95% CI: 0.715, 0.775) at person level, 0.771 (95% CI: 0.746,0.796) at the anterior segment level, 0.795 (95% CI: 0.766–0.824) for the upper anterior sextant and 0.905 (95%CI: 0.895–0.915) for the lower anterior sextant (Ramesh et al. 2022). From these findings’ researchers advocated BEWE was a more appropriate screening tool (Ramesh et al. 2022). On the other hand, recent best-evidence statements published postulated that the most important indication to intervene is driven by the needs of the patient and that treatment may only be indicated in the most severe category that impact negatively on a patient’s quality of life (Bartlett and O’Toole 2021). Inter-examiner calibration can be achieved through the use of dental casts and dental photographs which can be performed remotely, based on findings from training of four consecutive cohorts of first year postgraduate dental students (Mehta et al 2020). Following the training and written guidance the postgraduate students repeated their scores for the three cases demonstrating low,

medium and severe wear (Mehta et al. 2020). Mehta and co-workers found that the mean improvement in agreement with the 'gold standard' score improved by 15.6% and 15.3% for the medium and severe cases, which were statistically significant (Mehta et al. 2020). More recently research has focused on longitudinal monitoring of erosive wear through combining the BEWE index with digital 3D records of oral conditions. This appears to improve practitioner outcomes with respect to early diagnosis, monitoring and managing erosive tooth wear based on a retrospective longitudinal study of 120 orthodontic patients in Belgium (Marro et al. 2018).

1.3.5 Recording of dental trauma

Retrospective epidemiological research describing the incidence of dental trauma is abundant in the literature (Andersson and Andreasen 2011; Bastone et al. 2000; Glendor 2008; Lam 2016; Magno et al. 2020). A major disadvantage of retrospection is that certain soft and hard tissue injuries may not be evident at the time of examination, leading to under reporting (Bruggesser et al. 2020). Other injuries may also be omitted if there are no symptoms or if restorations have already been completed or the patient's recall of the event is poor (Bastone et al. 2000). Comparing data from different studies has been challenging due to differences in definitions and use of a range of classification systems (Lam 2016). Most classifications are modifications of the Trauma Index developed by the World Health Organization (1978) of which itself was developed as a modification of the classification developed by Sweet in 1955 (Sweet 1955; World Health Organization 1995). A merit of the Trauma Index system was its simplicity as luxation injuries were simply grouped together (World Health Organization 1978). The index subsequently developed by Andreasen allowed for minimal subjective interpretations and described injuries to the internal structures of the mouth, which was favoured by clinicians at the time for its ease of data collection but was not sufficient to inform and direct appropriate treatment based on best available evidence (Andreasen 1981; Bastone et al. 2000). Injuries to the alveolar socket and fractures to the mandible and maxilla are not grouped under oral injuries within the WHO standards but are instead classified separately in Andreasen's system (Bastone et al. 2000). However, this was an open-ended group which researchers postulated that it allowed for "other injuries including laceration of oral soft tissues" which may lend themselves to misinterpretation by researchers and clinicians (Bastone et al. 2000). Subsequent trauma indices appeared as modifications of that proposed by WHO, yet much of the large-scale epidemiological research today still rely on the WHO Trauma Index to allow for collaboration and communication (Andersson et al. 2012; Lam 2016; Yeng et al. 2020). Most however, are retrospective in nature and are heavily influenced by recall bias and can be open to researcher interpretation to draw conclusions (Schuch et al. 2013).

1.3.5 Evaluation of periodontal status

An index commonly used during data collection for evaluation of periodontal health is the Community Periodontal Index for Treatment Needs (CPITN) which was developed in 1982 as a World Health Organisation (WHO) initiative (Cutress et al. 1987). The CPITN assesses the presence or absence of gingival bleeding on probing, presence of supra and subgingival calculus and periodontal pockets using a dedicated 0.5mm ball tip probe (Ramachandra et al. 2009). The worst score in each sextant is recorded to estimate an individual's disease severity with recommendations for appropriate treatment. The main advantages of using this method included its simplicity, speed, low cost and international uniformity in research publications (Dhingra & Vandana 2011).

Despite these clear advantages in epidemiological research, it is important to be aware of its limitations (Baelum and Papanou 1996). In that paper they discussed and determined that the hierarchical principles underlying its use were not universally valid, as disease activity and rate of progression were not always clear (Miller et al. 1988). However, there was evidence to show that periodontal pocket depths can be phasic due to both biological and operator factors (Lafzi et al. 2007). One study showed that probing can produce an instant but transient shock in gingival tissues, thus, if a site is immediately re-probed then the second measurement could be influenced by the first (Clark et al. 1992). Furthermore, the partial recording approach may underestimate the prevalence of deep pockets and its use may yield extensively distorted estimates of the prevalence and severity of periodontal destruction in a given population (Baelum & Papanou 1996). A study conducted by Benigeri and colleagues on 2110 subjects between September 1994 and July 1995 found that only 8.5% of adults had a pocket of 6mm or deeper if probing just 2 sites, However, those increased to 2.5 x higher (21.4%) if probing was completed all around the tooth (Benigeri et al. 2000). Based on these limitations, the WHO proposed some modifications in 1997. The CPITN index was modified to the Community Periodontal Index (CPI) through inclusion of measurements of "loss of attachment' and elimination of 'treatment needs' categories and was then included as part of "WHO- Oral Health Surveys" to show the history of previous disease and potential resolution (Dhingra & Vandana 2011). Although this system still only analysed a limited number of teeth, it has been shown to be representative of full mouth records when identifying treatment need (Dhingra & Vandana 2011). This was demonstrated by Baelum and co-workers where they compared the results of full mouth examination of periodontal tissues with the results of examining only with CPITN selection teeth (Baelum et al. 1993). This research group used three calibrated examiners to review 1131 participants and found that despite under estimation of moderate or deep pockets it was well suited to identifying persons who are relatively healthy and therefore a good indication of establishing treatment need and initiation (Baelum et al. 1993). The CPI was therefore still considered useful in periodontal research, especially to reduce the time for

examination when dealing with a large population where a number of other oral conditions were to be examined. In addition, this method allowed the "collaboration of preventive and therapeutic programmes as well as the quantification of biological and environmental risk factors related to the disease onset and progression" as it could readily be communicated amongst researchers to develop appropriate treatment intervention guidance as well as provide a template for future research (Dhingra & Vandana 2011). These shortcomings in the use of the CPITN system led to the development of the Periodontal Screening and Recording (PSR) Index (Dye and Thornton-Evans 2007).

The Periodontal Screening and Recording (PSR) Index is a simplified and efficient method to assess periodontal health and identify patients requiring further periodontal evaluation or treatment (Rams and Loesche 2017).

Assigned PSR sextant score	Deepest Sextant Probing Depth (mm)
0 to 2	≤3
3	4 to 5
4	≥6
X	Not applicable if <2 teeth in sextant

Table 1.2 Periodontal Screening and Recording Index.

The index was developed in the early 1990s as a collaborative effort between the American Dental Association (ADA) and the American Academy of Periodontology (AAP) (Landry and Jean 2002). The PSR Index divides the dentition into sextants and uses a World Health Organisation (WHO)-approved periodontal probe with a colour-coded band (3.5mm to 5.5mm) to facilitate accurate probing depth measurements. The index scores range from 0 to 4, with higher scores indicating greater severity of periodontal disease. Patients with a PSR score of 3 or 4 in any sextant typically require further evaluation and possible periodontal treatment (Rams and Loesche 2017). Recent research tended to use the Periodontal Screening and Recording Index (PSR) or a slight modification, by only probing specific teeth, due to its speed, inexpensive equipment and necessary training requirement for intra- and inter-examiner reliability (Charles and Charles 1994). It was championed for its simplicity and previous research conducted by Piazinni found PSR to be on average nine times faster than a conventional evaluation (Piazinni 1994). Piazinni found that in the 26 young patients (age 3-20 years old) there was no difference between the PSR and full mouth assessment in diagnosis and clinical management, however, no reference to sensitivity or specificity for either index was present (Piazinni 1994). In addition, this

index showed significant associations with probing depths and attachment levels when compared to radiographs (Khocht et al. 1996). Moreover, patients appeared to relate better to the numerical values used in the PSR system when educating patients on clinical findings due to their simplicity in a study carried out on a randomly-selected military population (Covington et al. 2003). However, critics of this index have highlighted that it can underestimate the level of periodontal involvement, and the asterisk code does not specify which method is to be used for detection of more severe periodontal abnormalities (Khocht et al. 1996; Landry and Jean 2002).

1.3.6 Oral health-related quality of life (OHRQOL)

The importance of Health-related quality of life (HRQOL) assessments have been recognised by researchers for some time as it goes beyond direct measures of population health, life expectancy, and causes of death, and focuses on the impact health status has on quality of life (Haag et al. 2017). From the late 1960s it has been an important tool in an attempt to evaluate and compare overall health and well-being within populations. However, the oral health-related quality of life (OHRQoL) did not develop until the early 1980s (Sischo and Broder 2011). This was in part due to the consensus at the time among researchers and practitioners dismissing the idea that oral health could be directly linked to overall health, due to the previous perceived disconnect between the medical and dental professions (Bennadi and Reddy 2013). At the time, it was believed that apart from pain and life-threatening cancers, oral disease did not have any impact on social life and it was only linked with cosmetic issues by the medical research community (Davis 1976). Likewise, others at the time argued that dental disease was one of the frequent complaints such as headache, rash, and burns that were perceived as unimportant problems in society at that time (Dunnell & Cartwright 1972; Bennadi and Reddy 2013). Modern research has aimed to establish the link between oral health and overall well-being as well as trying to demonstrate causation of diminishing one's quality of life (Naito et al. 2006; Rouxel 2018).

1.3.7 Oral health related quality of life versus Quality of life

Quality of life (QoL) is the term used to describe "what makes life worth living" (John 2021). Health-related quality of life (HRQoL) is a multidimensional component of the larger concept of QoL that is related to health (Locker and Allen 2007). HRQoL encompasses physical, mental and social components (Sun et al. 2018). Despite there being several definitions for HRQoL, there is broad agreement that HRQoL "represents the effect of a medical condition and/or its consequent therapy upon a patient" (John 2021). It is important to acknowledge that the patient's perception of their own health status is not a deterministic reflection of their physical health situation and

vice versa. Instead, it is shaped by individual factors (e.g., personality characteristics), environmental factors (e.g., physical but also societal environment) (John 2021).

Oral health is a component of general health and is primarily affected by oral diseases and systemic diseases. Oral health related quality of life (OHRQoL) is a component of HRQoL that encompass the mental, physical and social components of oral health and how they relate to the patient's quality of life (Locker and Allen 2007). They can have very specific impacts on patients. These impacts are represented by the concept OHRQoL, and relate to the effects of oral diseases and dental interventions on patients. In a patient centred approach, the reduction and elimination of the effects of oral diseases on the patient is the primary goal of oral health care. Dental interventions primarily should decrease patient suffering, thereby improving OHRQoL. It is clear that an interventions outcome should be perceived by the patient as beneficial; where OHRQoL is a tool used to measure that perceived benefits (Sun et al. 2018).

One researcher in particular, Colman McGrath has been involved in a number of publications looking at OHRQoL relative to specific dental interventions, such as following endodontic treatment, orthodontic treatment and comprehensive oral rehabilitation (Neelakantan et al. 2020; Yawary et al. 2016; Zhang et al. 2008). It was also demonstrated in a sample of 3000 UK residents, those with high levels of dental anxiety (Corah Dental Anxiety Scale $\geq$ 15) were approximately twice as likely to be among those experiencing the poorest "oral health on quality of life" (McGrath and Bedi 2004).

The importance of oral problems and the physical and psychological impacts that they may have on an individual's life has been considered essential (Spanemberg et al. 2019). Many countries have already begun to show positive results in participants who were induced to undergo small changes in their clinical state of oral health and their psychological state as part of preventative oral health programs, like that seen with schoolchildren (Spanember et al. 2019). Here researchers carried out a 1-month longitudinal study to see if the oral health status of 50 students (aged 11-12 years) and their oral health related quality of life changed after four sessions of an educational preventive programme (Amato et al. 2014). They found that in the studied sample, an "improvement occurred with respect to the severity of disease, intensity and extension of impacts and global ratings of oral health after 1-month follow-up" (Amato et al. 2014).

It can be concluded from these results, that clinical indexes, such as CPI alone, do not adequately reflect the state of oral health since they are not able to capture the functionality or the psychological state of the patient (Amato et al. 2014). Studies that have verified and evaluated quality of life and how it related to oral health have detected a low impact on individuals, which is inconsistent with the prevalence of oral problems within the society being investigated (Spanemberg et al. 2019). However, this may be due, in part, to the "flooring-effect" seen with OHIP questionnaires where it proves difficult to differentiate among people who have different

levels of minor issues (Hebling and Pereira 2007). Thus, individuals with limitations from a technical point of view may still feel satisfied with their daily life, and consider themselves as having a good quality of life (Spanemberg et al. 2019). When interpreting OHRQoL measurements there are clear benefits of using such tools to more effectively communicate between professionals and patients a measure of a clinical intervention (Bennadi and Reddy 2013). When using such tools, it's important to understand their limitations as a predictor for quality of life. Consideration should be given not only to the biological nature, but also the context of people, such as the family environment, cultural values and beliefs (Kandelman et al. 2008).

1.4 Data Collection and Management

1.4.1 Introduction

Epidemiological data management and data collection in dentistry involves the systematic collection, analysis, and interpretation of data on oral health and disease (Van den Broeck et al. 2013). These data are used to identify patterns and trends in oral health, inform public health policy and guide the delivery of oral health care (Vega and Coelho 2015). Data collection in dentistry typically includes information on oral health status, oral health behaviours, and access or barriers to oral health care. This information may be collected through a variety of methods, including surveys, interviews, clinical examinations, and integration of medical/dental records. Data management involves the organisation, storage, and analysis of this data, as well as the dissemination of findings to relevant stakeholders (Johnson et al. 2016). Epidemiological data management in dentistry is typically completed with the aid of validated data collection forms to collect and store data (Aimée et al. 2019). These systems allow for the efficient collection and analysis of large amounts of data, and can be used to track patient outcomes and monitor the effectiveness of oral health interventions (Tokede et al. 2016).

Data collection in dentistry is also undertaken on a large scale through national oral health surveys which are conducted by national and international organisations. These surveys provide important information on the oral health status of populations and help identify patterns and trends in oral health (Gill et al. 2018).

1.4.2 Study Design

Much of the research to date on the oral health of elite athletes has collected data retrospectively, to test specific associations between an elite athlete's oral health and their sporting discipline (Bryant et al. 2011; Gallagher et al. 2018; Needleman et al. 2013). Unfortunately, a major disadvantage of retrospective studies in this context is that certain dental and oral injuries may not always be evident at the time of the examination if the injury occurred sometime beforehand (Bruggesser et al. 2020). Moreover, injuries may also be missed if signs and

symptoms do not exist at the time of examination (Bartone et al. 2000). Another shortcoming of retrospective studies is that patient recall of the injury may not always be accurate if the incident occurred sometime before the examination (Glendor 2008). Clearly, there is a particular demand for prospective studies when assessing incidence of dental trauma in sport. One such application could be a randomised intervention to investigate the actual protection offered by mouthguards and faceguards in in contact sports (Sigurdsson 2013).

1.4.3 Data Collection

There are several quantitative and qualitative methods of data collection that are commonly used in dental research, including:

1. Surveys: Surveys are one of the most common methods of data collection in dental research. They can be administered in person, by phone, or online, and can include both closed- and open-ended questions. Surveys are useful for collecting information on oral health behaviours, attitudes, and access to oral health care (Beltrán-Aguilar et al. 2003).
2. Interviews: Interviews are a qualitative method of data collection that allows researchers to explore a subject in depth. Interviews may be conducted in person, by phone, or online, and can include both open-ended and structured questions (Gill et al. 2008).
3. Clinical Examinations: Clinical examinations are used to collect information on oral health status. These exams typically include a visual and tactile examination of the teeth, gingivae, and oral tissues, and may also include diagnostic tests such as radiographs (Helöe 1972; Vandenberghe et al. 2010).
4. Medical Records: Medical records are a valuable source of information on oral health status and treatment history. Researchers may use medical records to collect data on patient demographics, oral health status, and treatment outcomes, but this is becoming increasingly difficult with the inception of GDPR compliance and modern research ethical requirements in Europe (Kirwan et al. 2021). It is also dependent on the quality of notes recorded, which can be from a number of sources (Filker et al. 2009).
5. Biomarkers: Biomarkers are molecular, cellular or physiological indicators of a biological state or condition, such as salivary markers used for caries assessment (Gao et al. 2015). They are used in dental research to measure oral health status, disease progression, and treatment outcomes (Hedge et al. 2019).
6. Electronic Health Records (EHRs): EHRs are increasingly being used in dental research as a source of data. They are useful for collecting data on patient demographics, oral health status, treatment history, and outcomes (Cederberg et al. 2015).

It is important to note that dental research can involve the use of one or more data collection methods. The choice of method will depend on the research question, the population being studied, and resources available (Gill et al. 2008).

1.4.4 Quantitative Data

The majority of dental research has been conducted using quantitative methodologies, fuelled laterally by the drive for evidence-based dentistry (Stewart et al. 2008). Quantitative research provides quantified answers to research problems and is associated with objectively measurable experimental research (Chai et al. 2021). This type of data refers to diagnostic information that can be measured and expressed numerically, usually through the use of standardised indices (Stewart et al. 2008). Quantitative data may demonstrate clinical measurements, the results of OHIP scores or dental anxiety scores, and demographic data (Cohen 2001).

1.4.5 Qualitative Data

Qualitative research does not seek to provide quantified answers to research questions (Masood et al. 2010). Instead, it is associated with more observational types of research (Chai et al. 2021). Qualitative approaches are therefore commonly used to explore, interpret, or obtain a deeper understanding of particular aspects of human beliefs, attitudes or behaviour, such as people's personal experiences and perspectives on services provision or adherence to programmes (Burnard et al. 2008). Qualitative research is therefore better suited to research where little is already known or understood that as a result of their unique nature, are generally not amenable to quantitative approaches (Chai et al. 2021). It can also supplement quantitative research to help ascertain patient perceptions on oral health impact as well as gain further understanding for methods of appropriate behavioural change strategies (Jeggle et al. 2019). Such qualitative research is typically used in research into behaviour change of athletes for performance of dietary adherence (Draper 2009; Bentley et al. 2019; Bentley et al. 2020; Bentley et al. 2021).

1.4.6 Data Capture

Paper-based data capture (PDC) and electronic data capture (EDC) are both methods used in research to collect, store, and analyse data. Each method has its own advantages and disadvantages. Paper-based data capture is a traditional method of data collection and involves the use of paper forms, typically in surveys. This method is relatively simple and easy to use, and does not require any specialised equipment or training (Walther et al. 2011). Data can be collected in any location and can be shared among researchers. However, paper-based data capture also has some limitations. It can be time-consuming and prone to errors, such as missing data or incorrect entries (Coons et al. 2009). It also makes it challenging to validate the data and

data sharing can be challenging with conventional paper records (Coons et al. 2009). This might be due to the time taken to digitise data as well as the time taken to try and avoid data transcription errors or review data for entry errors (Walther et al. 2011).

EDC, on the other hand, involves the use of electronic devices, such as computers or tablets, to collect and store data (Benoit et al. 2022). This method allows for real-time data entry and eliminates the need for manual data entry. EDC also makes it easier to validate data, as electronic systems can be programmed to check for errors and inconsistencies (Kopycka-Kedierawski et al. 2019). Additionally, EDC allows for remote data collection, and enables data sharing and data analysis in real-time (Kopycka-Kedierawski et al. 2019).

However, EDC also has some limitations, such as the need for specialised equipment and training, and the potential for technical problems or data breaches. The choice of data capture method will depend on the research question, the population being studied, and the resources available (Benoit et al. 2022). Both paper-based and electronic data capture methods have their advantages and disadvantages, and it's important for researchers to consider the pros and cons of each method before deciding which one to use.

1.4.7 Comparison of paper and electronic data capture

Research conducted by Kopycka-Kedierawski and co-workers evaluated and compared electronic and paper modes of data capture in a study on the management of dentine hypersensitivity (Kopycka-Kedierawski et al. 2019). They found that the electronic mode of data capture was as "operational as the traditional paper mode, while also providing the advantages of eliminating data entry errors, not involving site research coordinators in measuring the patient-reported outcomes, and not incurring additional costs and potential delays due to mailing study forms" (Kopycka-Kedierawski et al. 2019). According to Coons the adaptation of electronic data capture to patient reported outcomes avoided secondary data entry errors, allowed easier implementation of skip patterns and more accurate and complete data (Coons et al. 2009). This was echoed by research conducted by Bischoff-Ferrari et al. where they concluded that electronic data capture was a reliable assessment tool when compared to the pen and paper modality (Bischoff-Ferrari et al. 2005). They reported that 66% of subjects stated that both paper and computer formats were equally easy to use, and 26% thought that computer format was easier to use when compared with only 8% preferring paper format which was a statistically significant difference (Bischoff-Ferrari et al. 2005). During that study they also evaluated patients preferred data capture method, with more than 50% of patients preferring the computer format and just 9% expressing a preference for the paper format (Bischoff-Ferrari et al. 2005).

According to Schick-Makaroff and Molzahn, the benefits of capturing data electronically are: "(a) immediate access to retrievable data; (b) immediate scoring and presentation of data; (c)

prevention of errors in data entry; (d) improved data quality; (e) less missing information; and (f) high patient satisfaction with electronic platform and storage of longitudinal data" (Kopycka-Kedierawski et al. 2019 & Schick-Makaroff and Molzahn 2015). Electronic data capture was also proven to be more cost-effective when compared with traditional data collection methods such as pen and paper when the number of questionnaires distributed exceeded 1500 (Lofland et al. 2000). Where Langabeer and co-workers demonstrated the positive economics of reduced staff requirements, and costs associated with materials for pen and paper records, the resultant reduction in space required to store records could be utilised for increased revenue generating areas like surgery space (Langabeer et al. 2008). Certainly, within medical research there appears to be a researcher preference, perception of improved quality of care and overall cost reduction to using electronic records (Agha 2014; Lin et al. 2019).

1.4.8 Data Software

Data software used in dental research presents many challenges. Firstly, data collected about patients clinically lacks homogeneity, where both pre-clinical and clinical records involve diverse data types (Mjör 2007). Integrating and analysing this heterogeneous data historically had been challenging with the software available (Williams et al. 2004). Many previous software packages worked on closed systems with little ability to collaborate or transfer data sets easily (Williams et al. 2004). Market demand in recent years have forced developers to increase compatibility and provide open-source platforms (Hauge et al. 2010; Schwendicke and Krois 2022). In addition, data entry errors, missing values, and inconsistencies can compromise the quality and reliability of the research data (Williams et al. 2004b). It has been highlighted that ensuring data accuracy and completeness is crucial for robust analysis and to ensure quality of data (Williams et al. 2004). Moreover, patient data must be protected to ensure data collected complies with current GDPR regulations (Smyth et al. 2020). Therefore, data software used must have sufficient security measure and encryption protocols in place to protect patient data (Smyth et al. 2020). Furthermore, different dental practices and dental hospitals use different software and dental electronic health record systems, which can make data sharing and collaboration between clinicians and researchers difficult (Laske et al. 2016).

More recent data software developments used in dental research have aimed to allow interfacing with various electronic health record systems and various data formats to allow seamless data exchange (Schwendicke and Krois 2022). As dental research data sets grow in size and complexity, data software must be able to scale and accommodate this growth without sacrificing performance or functionality (LeCun et al. 2015). Data software should be accessible and easy to use for all researchers with various levels of technical expertise (Joda et al. 2020). This is achieved through intuitive interfaces, clear documentation and comprehensive support and training

resources (Joda et al. 2020). It is also desirable for research software to have analytical capabilities which could allow for analysis of complex data through built-in tools and libraries to facilitate researchers' analysis of the data collected (Carrillo-Perez et al. 2021). Moreover, with software and hardware continuing to develop it is important to ensure long term storage and management of data (Joda et al. 2021). Ensuring the integrity and accessibility of dental research data can be challenging particularly as systems evolve (Joda and Pandis 2021). Therefore, a key requirement of data software should have the provisions for long term data storage and efficient management (Hannigan and Lynch 2013). Increasingly data customisation and flexibility are required when using data software (Hannigan and Lynch 2013). This allows researchers to customise software specific and relevant to their needs. This should lead to improved accuracy, efficiency, integration, scalability, data security and cost effectiveness in performing research (Jensen et al. 2015). Dental research involves a variety of data types. Data software should therefore be sufficiently adaptable and customisable to meet the specific needs of the individual research as well as adapt to future indices based on best evidence available and guidance, where for example researchers have moved from quantifying caries prevalence with DMFT to ICDAS (Wagner et al. 2015). Finally, facilitating collaboration among dental researchers and institutions is vital to improve understanding and knowledge on a topic (Sheiham et al. 2011). Data software should therefore support collaborative features such as data sharing, version control and real-time communication tools (Balasubramanian et al. 2018).

KoBoToolbox is an open-source software tool developed by the Harvard Humanitarian Initiative (HHI) and the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) to support data collection, analysis, and management in humanitarian emergencies and other challenging field environments. KoBoToolbox allows users to build and deploy data collection surveys via web forms or mobile devices, store collected data securely, and visualize and analyse the data. Lakshminarasimhappa described KoBoToolbox as a free, open-source data collection platform that can be used to design, field, and manage data collection projects (Lakshminarasimhappa 2022). According to the home page of the KoBoToolbox website, some potential benefits of using KoBoToolbox over conventional methods of data collection include (KoBoToolbox no date. a):

1. Increased efficiency: KoBoToolbox allows for the rapid design and deployment of data collection forms, which can reduce the time and effort required to collect data.
2. Improved data quality: KoBoToolbox allows for the use of skip patterns, validation rules, and other features to ensure the quality of the collected data.
3. Enhanced data security: KoBoToolbox uses encrypted data transfer and storage to protect data from unauthorised access.

4. Increased flexibility: KoBoToolbox supports a wide range of data collection methods, including offline data collection, which can be useful in areas with limited internet connectivity.
5. Enhanced collaboration: KoBoToolbox allows for the real-time sharing of data with team members, which can improve collaboration and accelerate research efforts.
6. Reduced costs: KoBoToolbox is a free, open-source platform, which can reduce the costs associated with purchasing and maintaining proprietary data collection software.

1.4.9 Data Management

Data management and sharing have become increasingly important within dental research (Spallek et al. 2019). Reported advantages have focused on public health improvements and increased numbers and rates of citations (Yang and Maxwell 2011). Data management with standard sharing practices allows information from different sources to be collated in patient care systems and contribute to the overall learning on a topic (Spallek et al. 2019). These systems were described as 'Learning health systems' (Bernstein et al. 2015). This could instigate quality improvement initiatives whereby introduction of a new treatment protocol in management of an oral disease can be evaluated (Bader et al. 2001). Moreover, with the help of machine learnings and improvements in artificial intelligence, dental research learning health systems may help create predictive models for improved diagnosis and development of appropriate treatment approaches (Schwendicke et al. 2020). Furthermore, public health initiatives benefit from large-scale data gathered from populations as they identify risk factors and target preventive measures which is a key part of learning health systems (Kassebaum et al. 2015) Effective data management practices allow researchers to reanalyse and share data and reliably verify results, build and innovate existing research, and more easily replicate studies to train new researchers (Spallek et al. 2019). Effective data management and sharing can reduce unnecessary duplication of research and minimise wasting resources as well as contribute appropriately to existing research (Pham-Kanter et al. 2014).

1.5 Literature review conclusion

Following a review of the literature it is clear that further well controlled and validated research is needed in the developing field of sports dentistry. It is important to acknowledge the multi-disciplinary nature of oral health evaluation in elite athletes so that appropriate and effective exploratory research can be carried out to build on existing data. New data and insights will hopefully lead to greater understanding to help develop and guide further research as well as ultimately target and provide better oral health care for this population.

Increasing evidence has suggested that a high prevalence of oral diseases in the elite athlete population exists. The aim of the current study was to mirror and build upon existing research methodologies and apply it to our elite athletes in Ireland. The objectives were to describe the oral health of elite athletes in Ireland, the prevalence of oral diseases such as dental caries, periodontal disease and dental erosion as well as briefly describe dietary habits.

1.6 Aims and Objectives

The primary aim of this research was to:

1. To describe the oral health of elite athletes in Ireland.

The main objectives of this research were to:

1. Record oral health status of athletes using validated clinical indices so that comparisons could be made with existing research.
2. Assess the impact of oral disease on sport performance and participation.
3. Record dietary patterns, oral health practices and supplement use.
4. Contribute data to the existing available literature on the oral health status of elite athletes.

2. Materials and Methods

2.1.1 Literature review

A review of the literature was conducted to inform the research. A review of the literature was conducted to ascertain appropriate validated and comparable dental clinical indices as well as appropriate validated questionnaires applicable to an elite athlete population. Current available research was also reviewed as to appropriate clinical examination equipment and conditions so that results obtained could be comparable with existing available data.

2.1.2 Study design and rationale

Following a review of the literature, existing research methodologies with similar aims and objectives were appraised and used to help formulate an appropriate study design. A cross-sectional study design was chosen for this this research as it was both time efficient and cost effective to explore current disease prevalence within the elite athlete population in Ireland. It was hoped that the data collected could lead to identification of potential associations between oral health status and factors such as dietary intake, oral hygiene practices, training regimen and sport types. The description of the population could be used to generate hypotheses and direction for further research, such as the specific causes of oral health problems or the effectiveness of implemented preventative measures. It was also appreciated that data collection may be difficult due to limited access to this specific population as well as restrictions as a result of the Covid-19 pandemic.

Cross-sectional studies cannot establish causality due to their observational nature and the lack of temporal information (Rothman et al. 2008). As a result of this, they can only show associations between the variables explored. Furthermore, as data is collected at a single point in time, it is difficult to establish whether the exposure or risk factors preceded the outcome measured or vice versa, leading to temporal ambiguity (Rothman et al. 2008). In addition, it is also evident that there are considerable selection bias issues in the access to specific athletes at particular training camps and the willingness of athletes willing to participate (Sisjord and Kristiansen 2009).

The study's findings may not be generalisable if the sample of elite athletes is not representative of the Irish athlete population. However, it was attempted to mitigate these issues through distribution of participation leaflets through Sports Ireland Institute (SII) and across all sporting disciplines. In addition, there is also a potential for recall bias (Jain 2017). With the analysis of dietary habits and questionnaires relating to trauma occurrence and effect on training, participants may have challenges accurately recalling past event or behaviours, which may introduce errors and bias into the study findings (Gabbe et al. 2003; Jain 2017). Following appraisal of current available literature this study design was considered appropriate so that

relevant and meaningful comparison could be made to similar existing research that had access to a much larger and broader elite athlete population (Needleman 2013).

2.1.3 Ethical approval

As per the Dublin Dental University Hospital Research Ethics Committee guidelines ethical approval was sought and granted by the Faculty of Health Sciences Research Ethics Committee at Trinity College Dublin following submission of relevant application (Appendix 1). Elite athletes were then invited to participate in the study and provided with a participant information leaflet and informed consent form (Appendix 2 and 3).

2.2 Equipment and modification of research setting

The appropriate equipment was selected and research setting modified according to guidance published by the World Health Organisation on Oral Health surveys where they described basic methods that encouraged researchers to conduct standardised oral health surveys that were comparable internationally (WHO 2013). The manual published by the World health organisation provided guidelines for assessing the oral health status of the (WHO 2013).

Research settings:

1. IIS Building, National Sports Campus, Abbotstown, Dublin, D15 Y52H, Ireland
2. National Rowing Centre, Farran Woods,, Ovens, Co. Cork, Ireland

2.2.1 Examination kit

Disposable examinations kits which were calibrated and standardised in accordance with WHO guidance were used. Sterile disposable dental tray examination packs were purchased from Clonallon, Northern Ireland (NI), each individually sterilised pack contained stainless steel instruments of a College tweezers 15cm, dental mirror with handle (size 4), dental probe no.8 with protective cover, flat laminate sheet (50 x 50cm), tray (17.3 x 10.1cm) and a basic periodontal examination probe (WHO probe).

Figure 2.1 Photograph of disposable examination kit used which contained sterile stainless-steel instruments.

2.2.2 Clinical examination

Physiotherapy beds were available at each setting which were adjustable in height so that subjects were examined lying supine or sat upright on the bed with the patient “standing behind or in front of the chair” (WHO 2013).

2.2.3 Lighting

As electricity was available at all locations, a lightweight portable examination light (in the blue-white colour spectrum) was used in accordance with WHO guidance (WHO 2013). Daray X200 LED mobile lights were used for the examinations (Gallagher et al. 2023; UCL Eastman Dental Institute 2017).

Figure 2.2 Daray X200 LED mobile overhead light unit.

2.2.4 Table or platform

A table or platform to hold the dental instruments and basins was available at each facility.

2.2.5 Seating of recording clerk

The recording clerk sat close enough to the examiner for instructions and codes to be easily heard and for the examiner to check that findings were being recorded correctly. This arrangement also enabled the recording clerk to check that the score recorded related to the correct region or tooth.

2.3 Data collection

2.3.1 Development of data collection sheet (Digital format)

Data collection sheets in conventional format for the purpose of the research aims and objectives were designed in accordance with World Health Organisation recommendations (WHO 2013). This was then used to guide the formation of a digital version of the data collection sheet using KoBoToolbox software. KoBoToolbox is an online suite of tools used to set up data collection sheets and other relevant research tools for field data collection (KoBoToolbox n.d.). A free account was generated at https://www.kobotoolbox.org/. Once an account was created and new project was generated in the dashboard. The drag-and-drop interface was then used to design and customise the data collection form. Using the template and user intuitive tools provided, validated questions were added according to their relevant type with set relevant constraints and validations. For some parts of the data collection form, the data manager of the research group used the XLSForm to design and generate the ICDAS input tables in a manner which was appropriate and similar to conventional paper-based form. The settings were then calibrated to allow display of correct project name, form title, and language as well as ensuring the ability to collect data offline by ensuring only settings that did not require internet access were utilised by selecting “Online-Offline (multiple submission)” (KoBoToolbox n.d. b). The generated form was then previewed in the form design section prior to its deployment. This enabled completion of the form as it would be used in the research setting.

At this stage it was ensured that all questions functioned as intended. The form was deployed for use and could be accessed by the data collectors through KoBoToolbox software. The form was then shared with the various devices used by the data collectors. Data collectors were provided with 64Gb iPads (9th Generation 2021) for data collection. Questions and their expected responses were designed and fabricated in a way to allow for efficient data analysis following data collection by incorporating relevant real time validation and subsequently reviewed in the preview form function and then trialled in the pilot study (Arqaam n.d.).

2.3.1.1 Summary of digital form and Formbuilder functions

Once the form content, format and layout were agreed by researchers, KoBoToolbox Formbuilder was used to construct an appropriate digital data collection form. Questions for the form were added by clicking the "+" button that is below every question. The name of the question was added, then "Add Question" button was clicked. The appropriate question type that was most applicable to the question function and intended response was chosen. A list of question types is illustrated in Figure 2.4, and a summary of response types relative to question types are illustrated in Figure 2.5. Question hints were then added in text format to provide extra instruction on how to appropriately answer the question by clicking "Question hint". An example was the "MEASURED HEIGHT" text input question had displayed a hint "In cm" so that the data would be inputted in cm and not feet and inches or metres.

If there were errors in questions they were then deleted and a new question added as changing a question type after it was made was not supported by the software. All questions and groups could then be moved to any position in the form. The software allowed for a drag-and-drop function, to position questions in the intended order to allow the most logical and efficient workflow.

Advanced features for questions were then modified by clicking the "Settings cog". This enabled implementation of relevant features such as skip logic, validating responses, setting question hints, and making a question required to proceed. Skip logic is a feature that changes which question or page a respondent sees next based on how they answer the current question. Collaboration between different researchers within the team was enabled by sharing permissions to help with form construction. The preview form function was periodically be used to assess form functionality. After testing the form amongst researchers, the form was deployed and tested for functionality in a pilot study.

2.3.1.2 Screenshots of construction of KoBoToolbox data collection form

The following images demonstrate the steps that were taken in constructing a digital data collection form using KoBoToolbox software following sign-up of a free account.

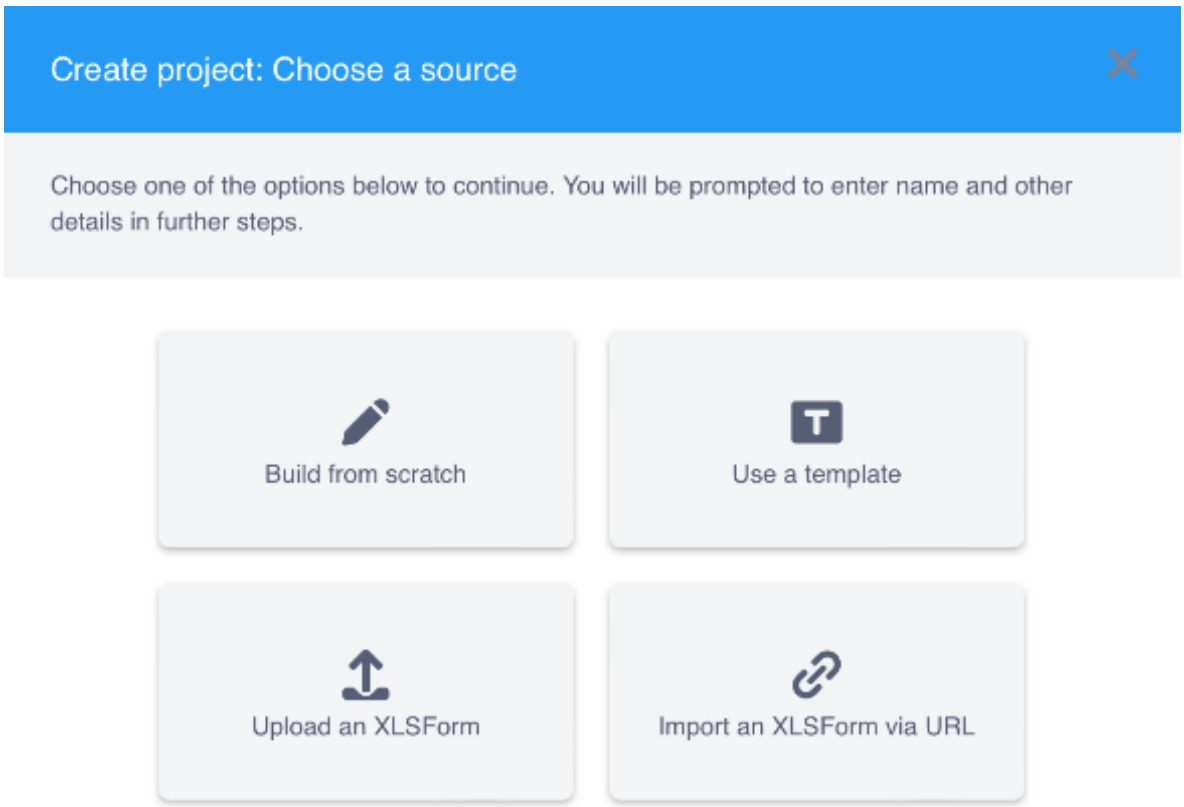


Figure 2.3 Creating KoBoToolbox data collection form; Build from scratch function.

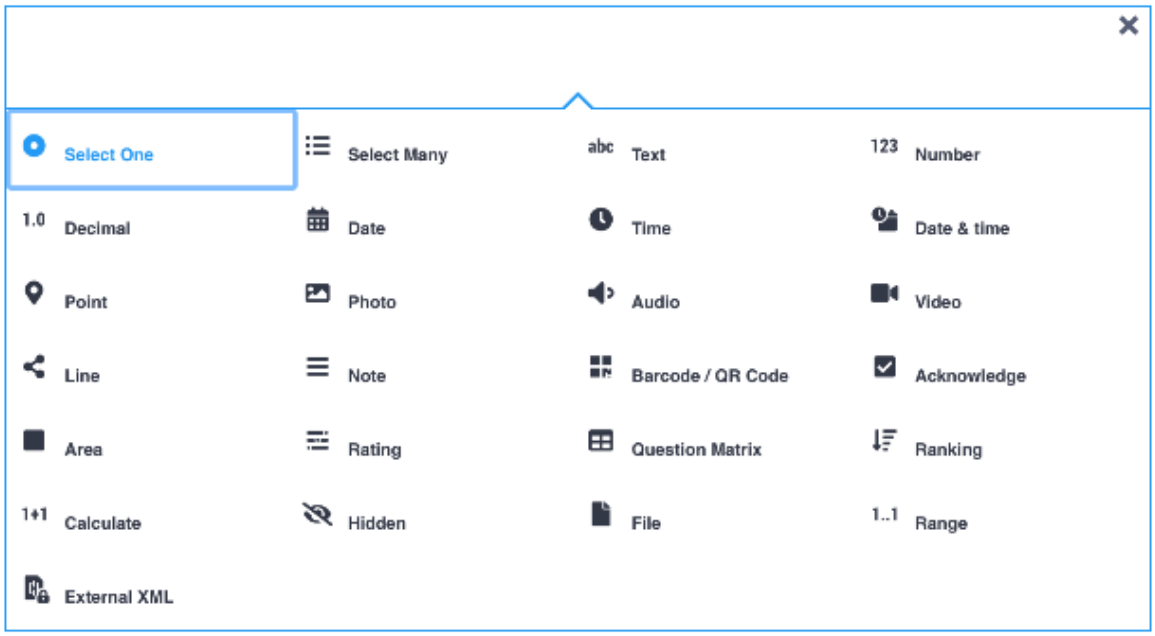
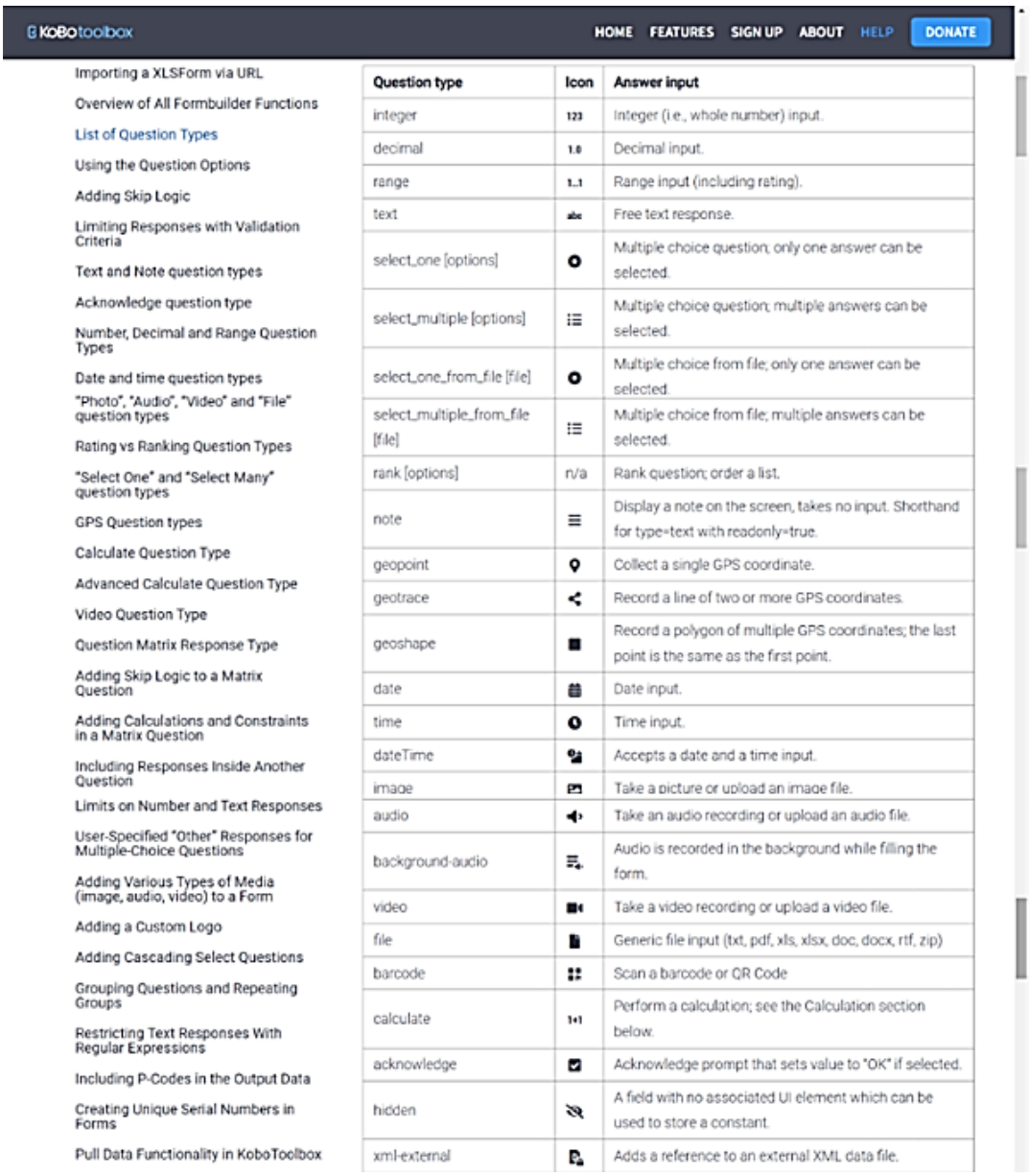


Figure 2.4 Table showing list of standard question types in KoBoToolbox software when build from scratch function used.



Question type	Icon	Answer input
integer	123	Integer (i.e., whole number) input.
decimal	1.0	Decimal input.
range	1..1	Range input (including rating).
text	abc	Free text response.
select_one [options]		Multiple choice question; only one answer can be selected.
select_multiple [options]		Multiple choice question; multiple answers can be selected.
select_one_from_file [file]		Multiple choice from file; only one answer can be selected.
select_multiple_from_file [file]		Multiple choice from file; multiple answers can be selected.
rank [options]	n/a	Rank question; order a list.
note		Display a note on the screen, takes no input. Shorthand for type=text with readonly=true.
geopoint		Collect a single GPS coordinate.
geotrace		Record a line of two or more GPS coordinates.
geoshape		Record a polygon of multiple GPS coordinates; the last point is the same as the first point.
date		Date input.
time		Time input.
dateTime		Accepts a date and a time input.
image		Take a picture or upload an image file.
audio		Take an audio recording or upload an audio file.
background-audio		Audio is recorded in the background while filling the form.
video		Take a video recording or upload a video file.
file		Generic file input (txt, pdf, xls, xlsx, doc, docx, rtf, zip)
barcode		Scan a barcode or QR Code
calculate	1+1	Perform a calculation; see the Calculation section below.
acknowledge		Acknowledge prompt that sets value to "OK" if selected.
hidden		A field with no associated UI element which can be used to store a constant.
xml-external		Adds a reference to an external XML data file.

Figure 2.5 Image displaying a high-level summary of each of the response types available to use in the XLSForm and formbuilder in KoBoToolbox software suite.

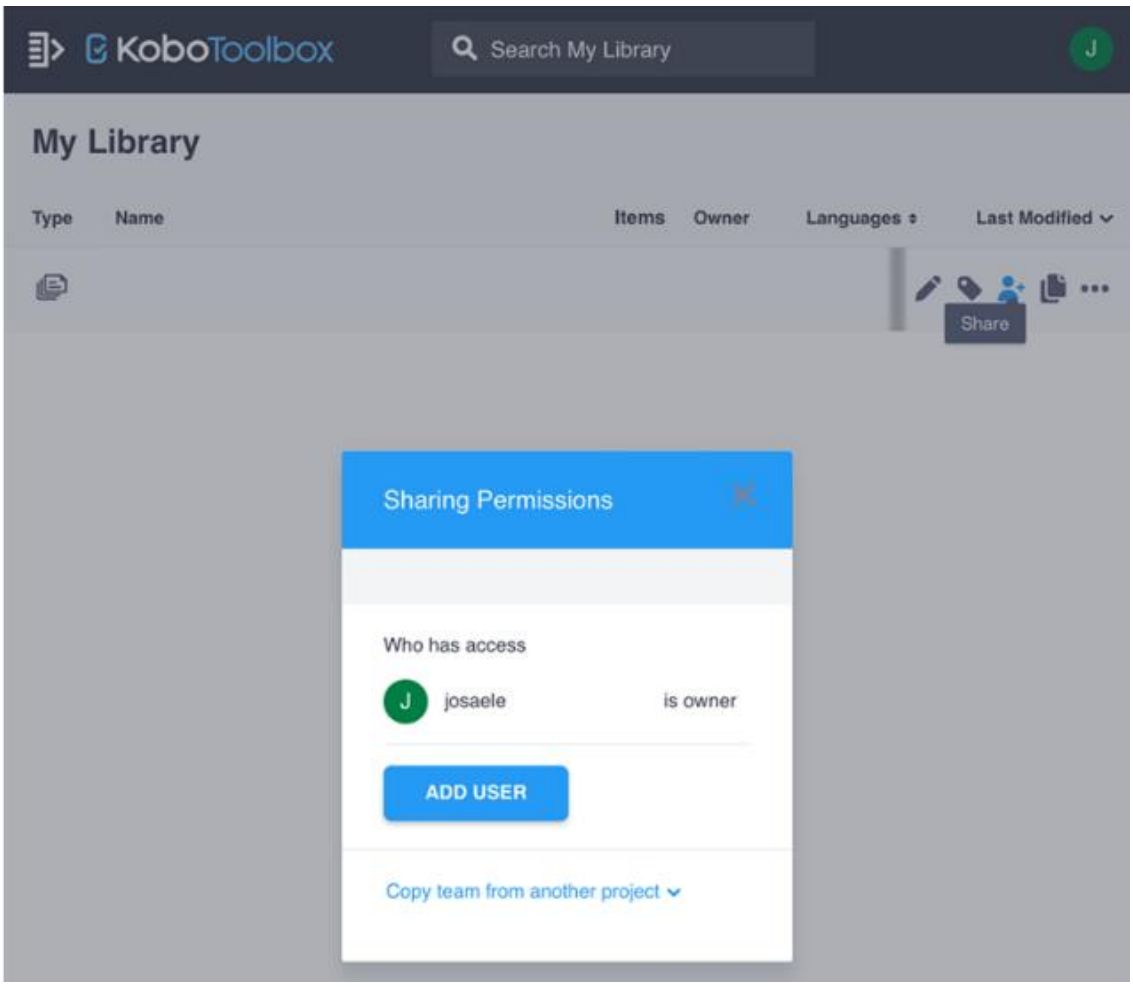


Figure 2.6 After initial construction of the form using Formbuilder function, 'Sharing Permissions' with other members of the research team to collaborate in KoBoToolbox form construction.

2.3.1.3 Screenshots of KoBoToolbox digital clinical data collection form

Screenshot images of the final digital data collection form used in the study are presented in Figure 4.1 to Figure 4.16 in Appendix 4. The digital data collection form was constructed using KoBoToolbox software which was compatible with both computer and the tablets (iPad 9th Generation 64Gb) used in the study.

2.3.2 Examiner calibration

All researchers were appropriately trained and calibrated in the clinical indices prior to data collection. Data collection was performed by two calibrated postgraduate Prosthodontic students.

2.3.2.1 ICDAS calibration

All researchers completed online training on the appropriate use and implementation of ICDAS at: www.iccms-web.com. Custom hands on and live training and calibration for the use of ICDAS was

then provided by Professor Nichola Innes (Dean Cardiff University Dental School) and Dr Daniela Raggio (Senior Lecturer Cardiff University Dental School). Training and calibration were carried out over to consecutive days for a total of 12 hours. Training and calibration were then assessed. A kappa score of over 0.9 was achieved when assessing the researchers for inter and intra examiner reliability. The Kappa score, or Cohen's Kappa coefficient, is a statistic that measures inter-rater reliability for qualitative (categorical) items. It is generally used to assess how well two clinicians are able to make the same judgments independently. A score of 0.9 can be interpreted as almost perfect agreement beyond what is expected by chance, suggesting that the tool, scale, or classification method being evaluated has excellent inter-examiner reliability, or is “very good” (Landis and Kock 1977).

2.3.2.2 Periodontal Screening and Recording

All staff were trained and calibrated in the use of this clinical indices as part of their ongoing in-house training at Dublin Dental Hospital, Trinity College Dublin.

2.3.2.3 BEWE calibration

Researchers were trained and calibrated on the appropriate use and implementation of BEWE using a series of study casts and clinical photographs. Inter and intra examiner reliability was not assessed for this index.

2.3.3 Pilot study

A pilot study involving eight postgraduate students was conducted in the Dublin University Dental Hospital. The pilot study was utilised to identify potential issues and facilitate troubleshooting of possible problems with use of equipment, transportation, disposal, allocation of appropriate timings and use of data collection using KoBoToolbox.

Participants involved in the pilot study were informed of the nature of the pilot study and informed consent provided. Participants were interviewed using the questionnaire integrated into KoBoToolbox software as per the main study. Upon completion of questionnaire and input into KoBoToolbox software, participants were clinically examined with one researcher carrying out the clinical examination and another inputting the data into KoBoToolbox. Researchers took it in turns to carry out the clinical examination and data entry for each participant. Each participant was examined under the same conditions as would be used in the study setting at the Sport Institute Ireland and Ireland Rowing facilities. The same disposable dental examination kits, gauze (to dry teeth), and light source that were to be used in the field were used in the pilot study. The use of compressed air to dry teeth was not practical. Therefore, it was considered standard protocol to

mitigate this practicality through an approved epidemiological modification which allows the use of gauze to dry the teeth instead (Pitts and Ekstrand 2013).

The pilot study allowed the development of an appropriate workflow and time allocation for field work involving elite athletes in the planned research settings.

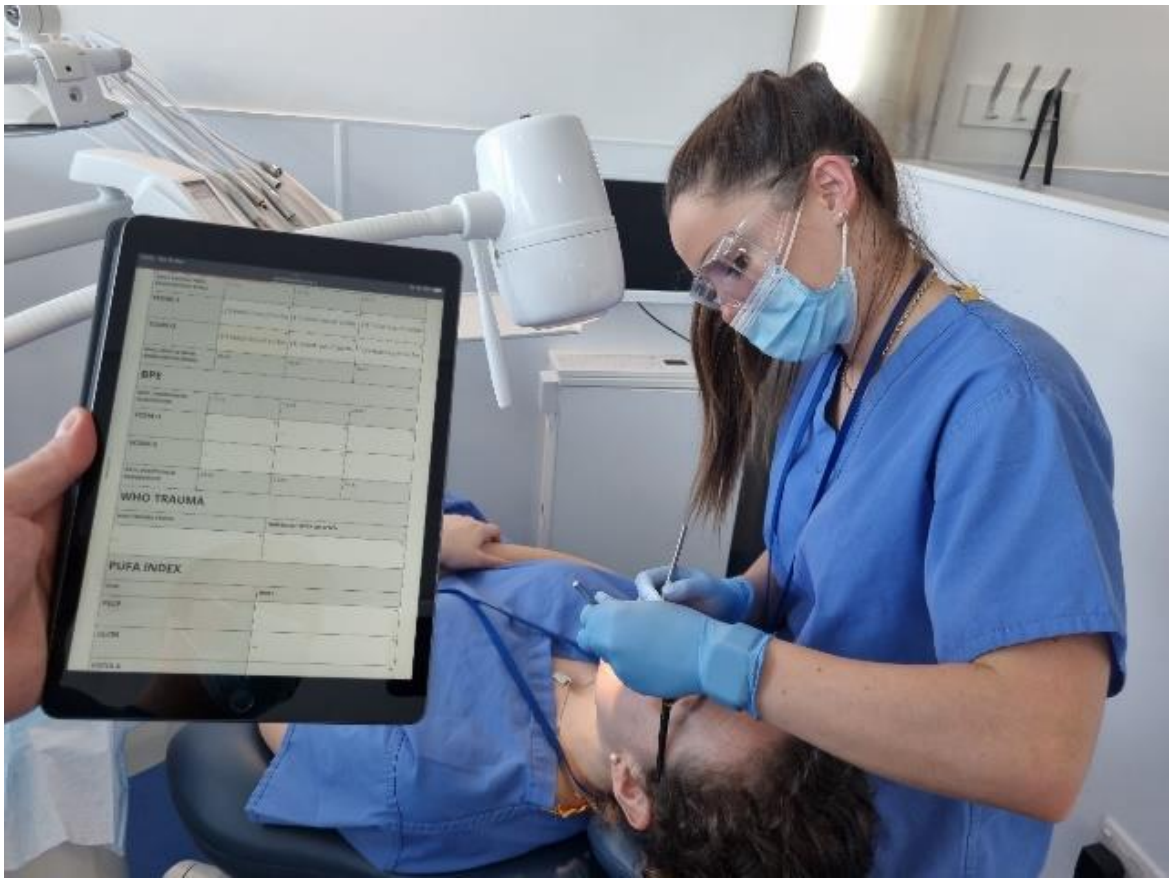


Figure 2.7 Image displaying clinical examination carried out during pilot study with clinical findings recorded electronically on iPad (9th Generation 64GB) using KoBoToolbox software form.

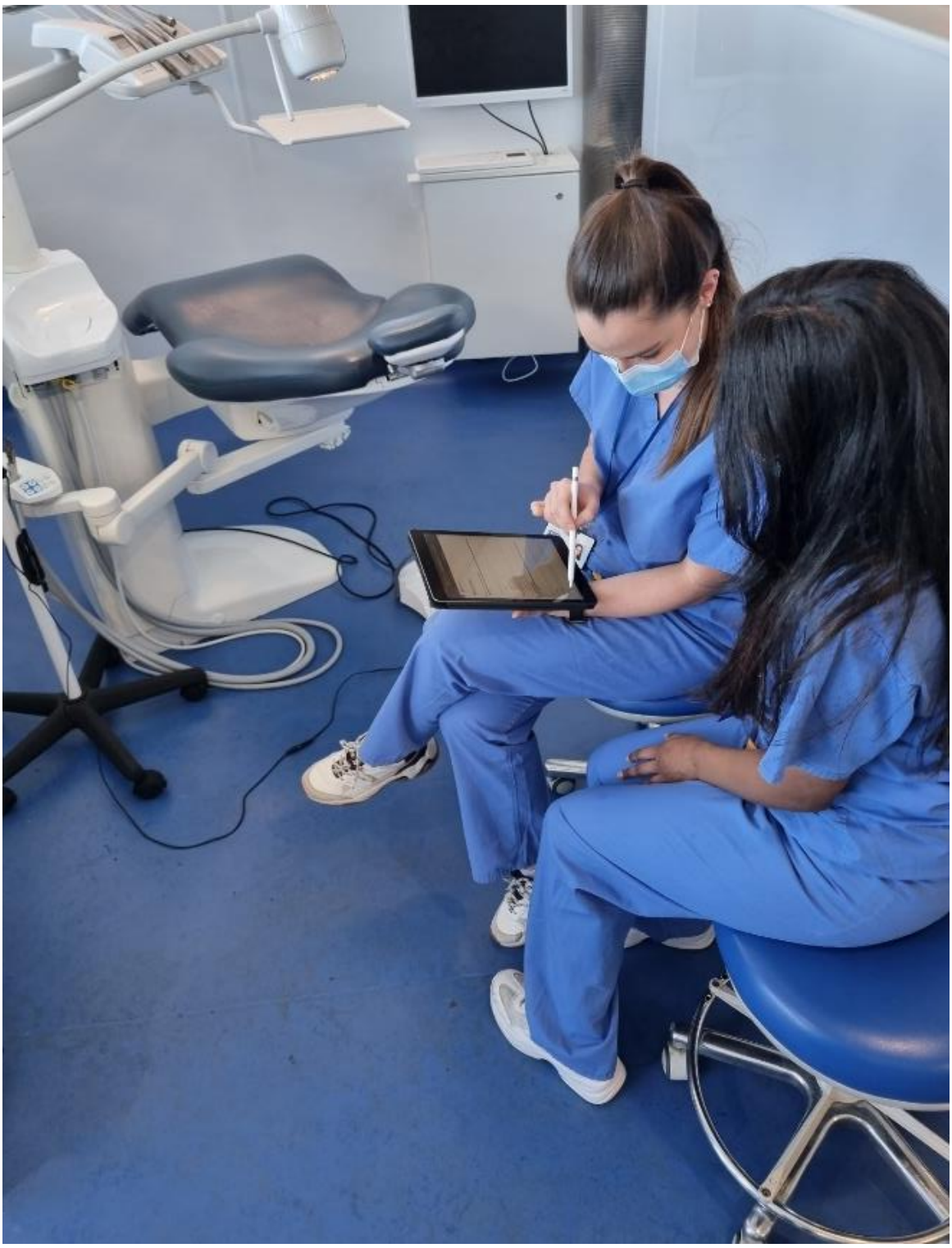


Figure 2.8 Image demonstrating completion of questionnaire during pilot study and recorded on iPad (9th Generation 64GB) using KoBoToolbox software.

2.3.4 Study Setting

Elite athletes representing Ireland and registered with Sports Ireland were invited to participate in the study between September 2021 and August 2022. Clinical examination of athletes was carried out at two training facilities in Ireland; Sport Ireland Institute, IIS Building, National Sports Campus, Abbotstown, Dublin, D15 Y52H, and the National Rowing Centre, Farran Woods, Ovens, Co. Cork, P31 K704.

Clinical examination of the athletes was completed on days around competition and training schedules between September 2022 and April 2023. Time was allocated following clinical examination for athletes to complete their Foodbook24 log following clinical examination and questionnaire which was scheduled following completion of the pilot study.

Figure 2.25 Image of Sport Ireland Institute, IIS Building, National Sports Campus.

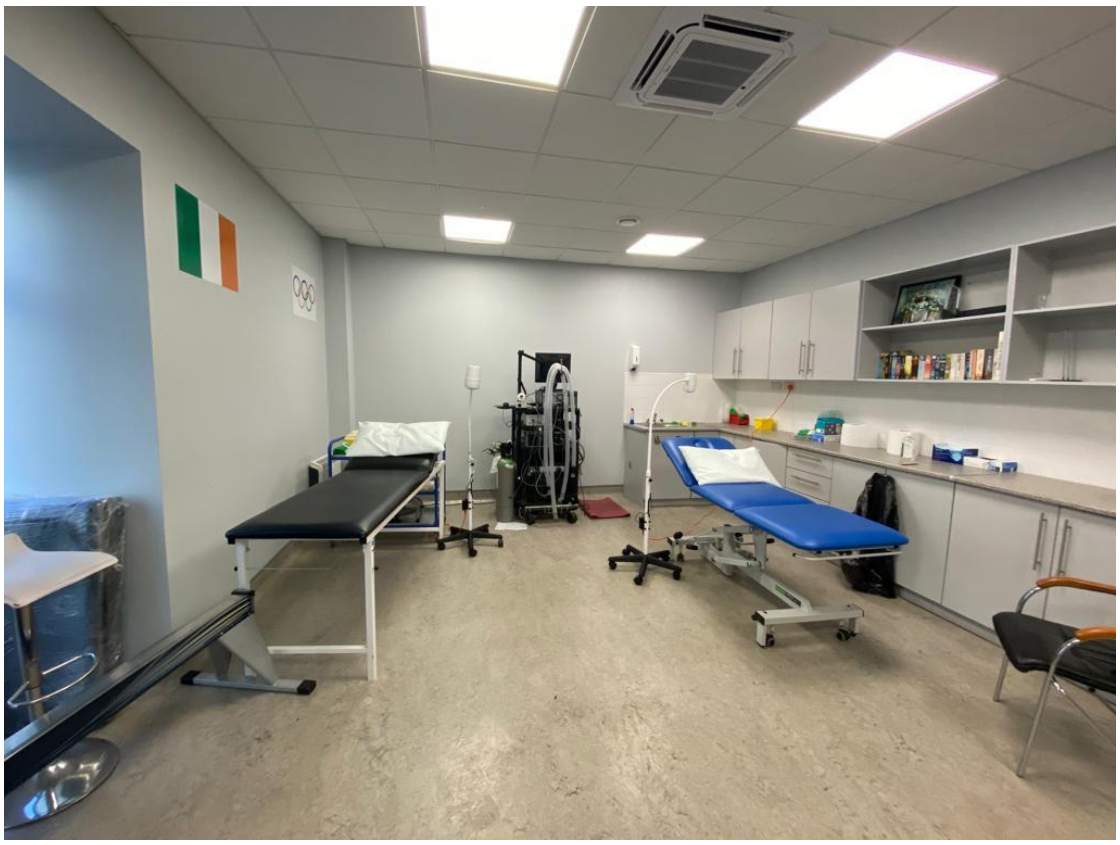


Figure 2.26 Image of National Rowing Centre.

2.3.5 Participant recruitment

Participant information leaflets were distributed to athletes registered with Sports Ireland via the head of performance nutrition, Dr Sharon Madigan. Dr Sharon Madigan worked closely with athletes competing in boxing, rowing, athletics, judo and cricket. Athletes who expressed an interest in taking part in the research were invited to take part if they were considered an elite athlete representing Ireland and registered with Sports Ireland. From this pool of participants, the following inclusion and exclusion criteria were applied;

Inclusion criteria:

- Healthy volunteers between the ages of 18 and 65 with the ability to provide informed consent.

Exclusion criteria:

- Cardiac conditions that would require antibiotic cover and limit examination.
- Pregnant women

2.3.6 Information sheet and informed consent

Each participant who volunteered and agreed to participate in the study was provided with a participant information leaflet (Appendix 2) and written informed consent information (Appendix 3) as per TCD Faculty of Health Sciences Research Ethics Committee requirements. Alison Porter

(Head of operation at SII) was appointed gatekeeper for the research project. The role of the gatekeeper was to protect the interests of the participants and to ensure that they are not under any pressure to participate. Potential participants were then given a 7-day consideration, “cool-off”, period. Participants were requested to read the information sheet during this time and then provide written informed consent prior to enrolling in the study. Contact details of the lead investigator and research supervisors were provided should any queries have arisen or any clarification be required. At the clinical examination and data recording visit a further explanation of the study and what it entailed was given to each participant prior to clinical examination, completion of questionnaire and completion of Foodbook24.

2.3.7 Data Sources/measurement

Data Collection: The data collection process involved a questionnaire, a clinical oral health examination and completion of a Foodbook24 diet diary.

Questionnaire: Participants completed a questionnaire to gather information on demographic data, sports discipline, oral health effect on training frequency and duration, dietary habits, oral hygiene practices, dental attendance, and history of dental injuries. The questionnaire was developed based on validated instruments from previous studies on athletes' oral health (Needleman et al. 2016).

Clinical Oral Health Examination: A standardised clinical examination was completed by trained and calibrated dentists to assess each participant's oral health status. The examination included the following components:

a. Dental caries: Caries experience was assessed using the International Caries Detection and Assessment System (ICDAS) index for permanent dentition and primary dentitions (if applicable).

b. Periodontal health: Periodontal health will be assessed using the Community Periodontal Index (CPITN) and the presence or absence of bleeding on probing (BOP).

c. Dental erosion: Dental erosion was assessed using the Basic Erosive Wear Examination (BEWE) index.

d. Dental trauma: A history of dental trauma will be recorded based on the participant's self-report and clinical examination findings using the PUFA index. The PUFA index has been used primarily in epidemiological studies to assess the public health burden of untreated dental caries. The index was proposed to address the shortcomings of traditional measures like DMFT that do not fully capture the public health impact of untreated dental disease, which may include pain, infection, and other complications. The PUFA index was introduced in dental research by Monse et al., in 2010, as part of an effort to provide a more comprehensive evaluation of the public health implications of untreated dental caries (Monse et al. 2010). It has since been adopted in

various studies worldwide to assess the severity and treatment needs of dental caries in different populations (Sharna et al. 2019).

2.3.8 Study Size

Data collection on participants commenced in September 2022 and finished in April 2023. As this was the first descriptive study of elite athletes in Ireland, as many subjects as possible were invited to attend through SII.

2.3.9 Quantitative variables

Quantitative variables were recorded in open-source software suite KoBoToolbox. This included age, height, weight, years in full time education, ICDAS, BEWE, BPE, PUFA indices and are displayed in the previous images.

2.3.10 Qualitative variables

Qualitative variables were also recorded. These included variables such as gender, ethnicity, occupation and highest education level achieved and are displayed in the images above.

2.3.11 Statistical Methods

2.3.11.1 Results

Descriptive statistics was used to describe the prevalence of disease in this population.

2.3.11.2 Participants

All elite athletes representing Sports Ireland were invited to participate in the study by head of performance nutrition Dr Sharon Madigan. Athletes who fulfilled were then given appointments for clinical examination and interview at their chosen training facility under standardised conditions. From this invitation, 96 athletes requested to take part in this study. This resulted in 88 athletes having a clinical examination, as 8 were excluded as they were under 18 years of age.

3. Results

3.1 Data management and analysis

Anonymised data were exported from KoBoToolbox to Excel for Windows version 10. Descriptive statistics were provided using mean or median and range depending on the distribution of the data.

3.2 Results

From the invitations distributed through SII, 97 athletes requested to take part in this study. This resulted in 89 athletes having a clinical examination, as 8 were excluded as they were under 18 years of age. A total of 89 athletes were recruited with full data available for descriptive analysis. Missing data was present for one participant due to issues with data transfer and will not be included in the analysis.

3.3 Characteristics of athletes

The mean age of the athletes was 25.6 years (range 18-53 years) and 55/88 (62.5%) were male and 33/88 (37.5%) were female (Figure 3.1). The majority of athletes identified as “Irish White” 68/88 (77.2%). In total, 83.0% of athletes (73/88) resided in the Republic of Ireland on a permanent basis, while 15 athletes permanently resided in Northern Ireland (Figure 3.2). In terms of education, 96.6% of athletes had completed education to a Leaving Certificate or higher, and 69.0% of athletes (59/88) had completed education beyond Leaving Certificate level.

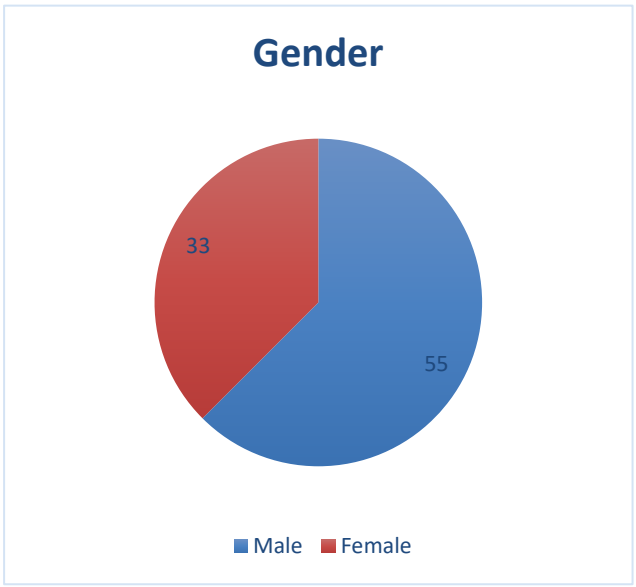


Figure 3.1 Pie chart demonstrating athlete gender distribution.

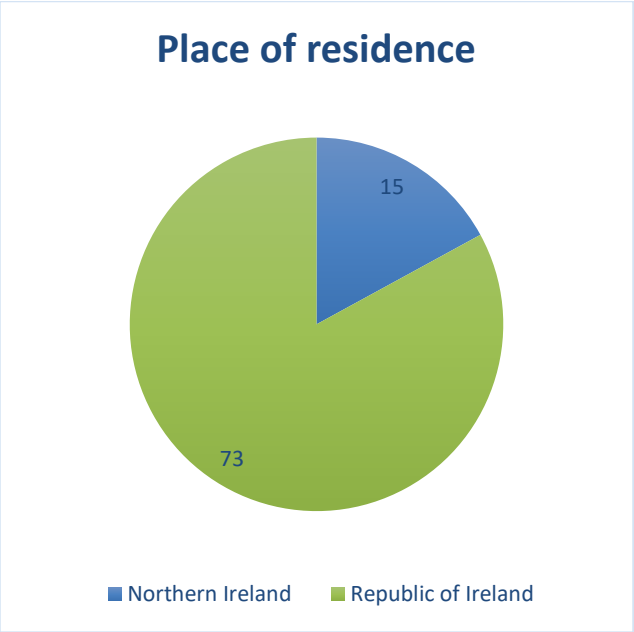


Figure 3.2 Pie chart demonstrating athlete place of residence.

Participants represented eight sporting disciplines with cricket, boxing and rowing being the most common. From the total of 88 athletes; 31 were cricketers, 22 boxers, 21 rowers, 6 paracyclists, 5 swimmers, 1 cyclist, 1 gymnast, and 1 triathlete.

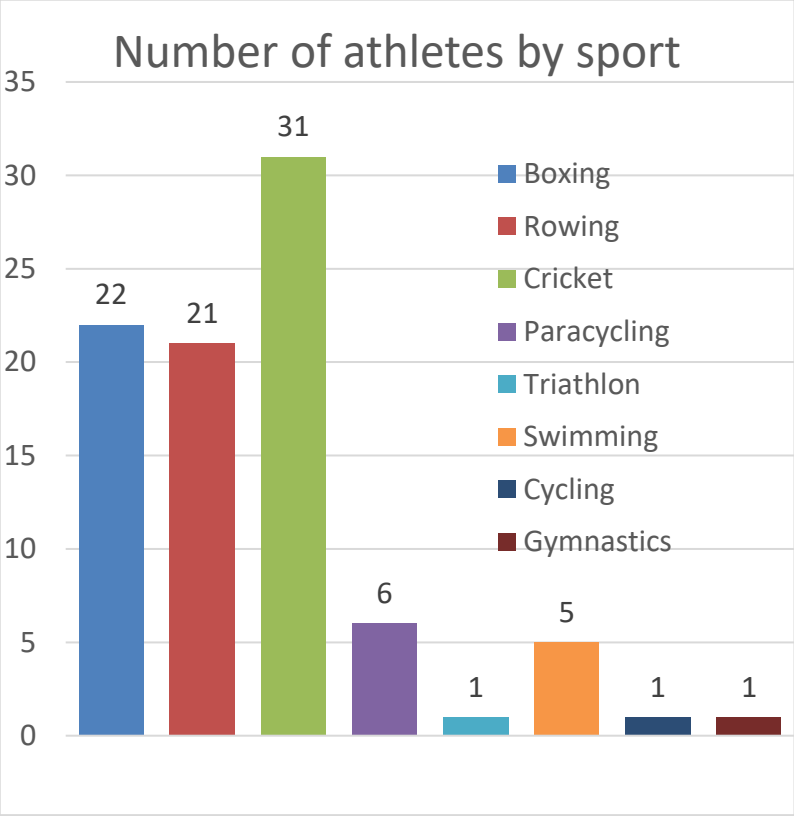


Figure 3.3 Bar graph demonstrating distribution of athletes by sport.

Nearly a third of athletes (30/88) reported not attending a dental visit within the last 12 months. Interestingly 90.9% (80/88) were given advice by a dentist or hygienist on how to look after their mouth, teeth and gums, but only 67.0% (59/88) had been given advice about their diets. In total, 14.7% (13/88) of athletes reporting no dental check-up visit in the last 2 years.

Only one athlete reported current use of tobacco, with 9.1% (8/88) reporting previous use and 89.8% (79/88) reporting that they had never used tobacco. Only one athlete reported previous use of smokeless tobacco with the other 87 athletes reported having never used smokeless tobacco. In total, 5.7% (5/88) of athletes used e-cigarettes with nicotine at the time with 4.5% (4/88) of athletes reporting previous use. The remaining 79 athletes reporting having never used e-cigarettes containing nicotine. Interestingly, one athlete reported previous use of e-cigarettes not containing nicotine with the remaining 87 athletes having never used e-cigarettes not containing nicotine.

3.4 Oral health

3.4.2 Athlete perception

Generally, athletes scored their perception of their general health more favourably than their oral health. With athletes perceiving their general health versus their oral health being very good by 61.4% (54/88) vs 15.9% (14/88) respectively, good as 35.2% (31/88) vs 51.1% (45/88), fair as 2.3% (2/88) vs 23.9% (21/88) and poor as 1.1% (1/88) vs 9.1% (8/88) (Figure 3.4).

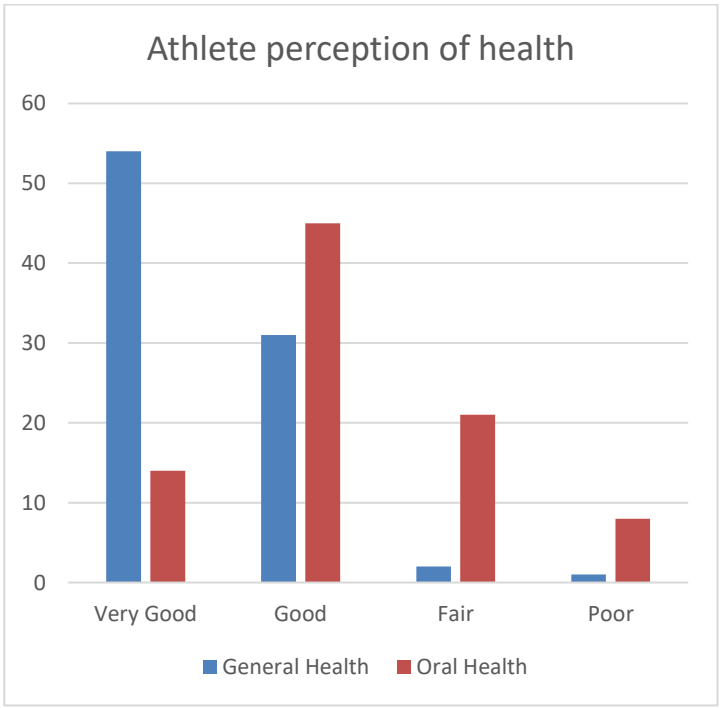


Figure 3.4 Athlete perceptions of own general versus oral health status.

3.4.2 Athlete oral health practices

The majority of athletes cleaned their teeth twice a day, both morning and at night-time (96.6%). Very few athletes brushed their teeth before a planned sleep during the day, but 14 athletes (15.9%) said they brushed their teeth after waking from a nap during the day. There were 15 athletes (17.0%) that said they would regularly brush their teeth at another time of the day in addition to morning and night-time (Table 3.1).

When do you clean your teeth?	Morning	Night-time	Before sleeping during the day	After sleeping during the day	Any other time during the day
Yes	96.6% (85/88)	96.6% (85/88)	3.4% (3/88)	15.9% (14/88)	17.0% (15/88)
No	3.4% (3/88)	3.4% (3/88)	96.6% (85/88)	84.1% (74/88)	83.0% (73/88)

Table 3.1 Toothbrushing habits of athletes.

There was a similar distribution of athletes using either a manual (65.9%) or a powered (54.5%) toothbrush to clean their teeth. The slightly higher proportion of manual toothbrush users was as a result of some 11 athletes (12.5%) favouring both. Almost half of athletes used interdental floss (48.9%). Almost all athletes (98.9%) used a fluoridated toothpaste with just one athlete opting to use fluoride free toothpaste due to personal concerns over fluoride. A similar proportion of athletes used mouthwash (40.9%) and chewed sugar-free chewing gum (42%), but only 16 athletes (18.2%) used both mouthwash and sugar-free chewing gum. Mouthguards were used by 26 athletes (29.5%) which is higher than the number of athletes competing in contact sports (22 boxers).

What oral health aids do you use?		
	Yes	**No**
Manual toothbrush	65.9% (58/88)	42.0% (37/88)
Powered toothbrush	54.5% (48/88)	45.5% (40/88)
Interdental (floss/interdental brushes)	48.9% (43/88)	51.1% (45/88)
Non-fluoridated toothpaste	1.1% (1/88)	98.9% (87/88)
Fluoridated toothpaste	98.9% (87/88)	1.1% (1/88)
Mouthwash	40.9% (36/88)	59.1% (52/88)
Sugar-free chewing gum	42.0% (37/88)	58.0% (51/88)
Gum shield	29.5% (26/88)	70. 5% (62/88)

Table 3.2 Oral health aids used by athletes.

In total, 38 athletes said that they could or probably could reduce snacking between meals if they thought it would keep their mouth, teeth or gums. A higher proportion (69.3%) of athletes said that they could reduce sugary drinks between meals. Over 80% of athletes said they could brush before sleeping, spit and not rinse toothpaste and use fluoridated toothpaste. In total 83% of athletes said they would use sugar free chewing gum and have regular check-ups with a dentist if they thought it would keep their mouth, teeth or gums healthy. However, five athletes (4 from RoI, 1 from NI) said that they would find it difficult to have regular visits to a dentist or hygienist. Table 3.3 summarises these findings.

If you thought it would keep your mouth teeth and gums healthy, do you think you could?				
	Yes	Probably	With difficulty	No
Reducing snacking between meals	26.1% (23)	17.0% (15)	20.5% (18)	36.4% (32)
Reduce sugary drinks between meals	69.3% (61)	11.4% (10)	8.0% (7)	11.4% (10)
Brush teeth before sleeping	97.7% (86)	2.3% (2)	0% (0)	0% (0)
Spit out don't rinse	81.8% (72)	10.2% (9)	3.4% (3)	4.5% (4)
Use fluoridated toothpaste	84.1% (74)	10.2% (9)	2.3% (2)	3.4% (3)
Use interdental floss/brushes	62.5% (55)	19.3% (17)	15.9% (14)	2.3% (2)
Use sugar-free chewing gum	83.0% (73)	11.4% (10)	2.3% (2)	3.4% (3)
Have regular visits to a dentist or hygienist	83.0% (73)	11.4% (10)	5.7% (5)	0% (0)

Table 3.3 Athlete recorded attitudes to potential behavioural change to improve oral health.

3.4.3 Teeth present, caries and restorations

The mean number of teeth per athlete was 30.0 (range 25-32). Almost three quarters of athletes presented with dental caries, ICDAS 4 or more, 72.7% (64/88). In terms of extent, an average of 7.4 teeth were affected by enamel or dentine caries for each athlete (range 0-27). Caries requiring intervention (ICDAS 4 or more) was an average of 1.75 teeth per athlete were recorded (range 0-9). An average of 5.1 restored teeth per athlete were found (range 0-17). In total, 50% of athletes (44/88) had lost or broken restorations (ICDAS 7), whereas 18.2% of athletes (16/88) had temporary restorations in place (ICDAS 8).

Key to two-digit codes in the ICDAS II scoring system	
Restoration and sealant codes	**Caries codes**
0 = Not sealed or restored	0 = South tooth surface
1 = Sealant, partial	1 = First visual change in enamel
2 = Sealant, full	2 = Distinct visual change in enamel
3 = Tooth-coloured restoration	3 = Enamel breakdown, no dentine visible
4 = Amalgam restoration	4 = Dentinal shadow (not cavitated into dentine)
5 = Stainless steel crown	5 = Distinct cavity with visible dentine
6 = Porcelain, gold, PFM crown or veneer	6 = Extensive distinct cavity with visible dentine
7 = Lost or broken restoration	
8 = Temporary restoration	**Missing teeth**
	97 = Extracted due to caries
	98 = Missing for other reason
	99 = Unerupted

Table 1.1 Table demonstrating key to two-digit codes used in the ICDAS II scoring system.

3.4.4 Dental Erosion

Dental erosion was present in 19.3% athletes (17/88). In those with erosion, the severity in the most affected tooth did not exceed moderate erosion (grade 2 BEWE).

3.4.5 Dental trauma

In total, 55.7% of athletes (49/88) reported no history of previous history of dental or orofacial trauma. In total, 20.5% (18/88) reported enamel fractures, with 11.4% (10/88) reporting enamel and dentine fracture. Trauma involving the pulp was found in 4.5% of athletes (4/88), 2 cricketers and 2 boxers. In total, 3.4% of athletes (3/88) reported missing teeth as a result of trauma, 2 rowers and 1 paracyclist.

3.4.6 Periodontal health

Gingivitis (basic periodontal examination codes of 1 or 2), was present in 46.6% of athletes (41/88). Periodontitis (basic periodontal examination codes of 3-4) was found in 53.4% of athletes (47/88). Whereas 89.8% of athletes (79/88) presented with basic periodontal examination codes

of 1, 3 or 4. Only 9.1% of athletes (8/88) presented with a basic periodontal examination where only codes 0 and 2 were present.

3.4.7 Impact of oral health on performance

There was a substantial self-reported negative impact of oral health on well-being and performance with 8.0% of athletes (7/88) reporting difficulties in participating in normal training or competition due to their oral problems.

In total, 10.2% of athletes (9/88) reported at least some reduction in training as a result of their mouth, teeth or gingivae. On further questioning, 2.3% (2/88) and 5.7% (5/88) reported a reduction in their competition and performance respectively. As much as 39.8% (35/88) had experienced pain from their mouth teeth or gums in the last 12 months. All athletes had expressed that their self-perceived oral health had negatively impacted them in some way 100% (88/88).

3.4.8 Athlete consumption of food and beverage

Over half of the athletes, 46 athletes (52.3%), reported eating sweets and/or chocolate more than 3 times a week. A lower proportion of athletes ate cakes, biscuits, puddings and pastries more than 3 times a week, 23 athletes (26.1%). A similar proportion of athletes consumed diet and non-diet fizzy drinks, the results of which are displayed in Table 3.4.

How many times a week do they consume the following:	Cakes, biscuits, puddings and pastries	Sweets and/or chocolate	Drink non diet fizzy drinks	Drink diet fizzy drinks or sugar-free soft drinks
6+ times a week	8.0% (7/88)	21.6% (19/88)	10.2% (9/88)	9.1% (8/88)
3-5 times a week	18.2% (16/88)	30.7% (27/88)	11.4% (10/88)	14.8% (13/88)
1-2 times a week	43.2% (38/88)	31.8% (28/88)	18.2% (16/88)	25.0% (22/88)
Less than once a week	14.8% (13/88)	11.4% (10/88)	12.5% (11/88)	15.9% (14/88)
Rarely or never	15.9% (14/88)	4.5% (4/88)	47.7% (42/88)	35.2% (31/88)

Table 3.4 Athlete reported consumption frequency of different foods and beverages.

3.4.9 When do you consume energy bars?

Table 3.5 displays athletes' consumption of energy bars around training and competition. Energy bars was an umbrella term used to define high calorie bars used to replenish glycogen levels as well as protein bars to aid muscle recovery. Consumption of energy bars was related to their purpose in replenishing glycogen or aiding muscle recovery and were therefore largely consumed before or after training and competition.

When do you consume energy bars?	Always	Sometimes	Never
Before training	4.5% (4/88)	27.3% (24/88)	68.2% (60/88)
During training	8.0% (7/88)	9.1% (8/88)	83.0% (73/88)
After training	12.5% (11/88)	34.1% (30/88)	53.4% (47/88)
Before competition	5.7% (5/88)	22.7% (20/88)	71.6% (63/88)
During competition	6.8% (6/88)	11.4% (10/88)	81.8% (72/88)
After competition	11.4% (10/88)	20.5% (18/88)	68.2% (60/88)

Table 3.5 Athlete reported consumption of energy bars around training and competition.

3.4.10 When do you consume energy gels?

Table 3.6 demonstrates the distribution of athlete consumption of energy gels around training and competition. The majority of athletes never use energy gels around training or competition. The proportion of athletes that did consume energy gels tended to use them during training (33.0%) or during competition (30.7%).

When do you consume energy gels?	Always	Sometimes	Never
Before training	2.3% (2/88)	6.8% (6/88)	90.9% (80/88)
During training	20.5% (18/88)	12.5% (11/88)	67.0% (59/88)
After training	0% (0/88)	5.7% (5/88)	94.3% (83/88)
Before competition	18.2% (16/88)	6.8% (6/88)	75.0% (66/88)
During competition	19.3% (17/88)	11.4% (10/88)	69.3% (61/88)
After competition	1.1% (1/88)	2.3% (2/88)	96.6% (85/88)

Table 3.6 Athlete reported consumption of energy gels around training and competition.

3.4.11 When do you consume sports drinks?

Table 3.7 outlines patterns of consumption of sports drinks around training and competition. In those who consumed sports drinks a higher proportion of athletes favoured consumption around competition (50.0%) rather than around training times (42.0%). However, over a third of athletes never consumed sports drinks.

When do you consume sports drinks?	Always	Sometimes	Never
Before training	8.0% (7/88)	25.0% (22/88)	67.0% (59/88)
During training	30.7% (27/88)	25.0% (22/88)	44.3% (39/88)
After training	17.0% (15/88)	20.5% (18/88)	62.5% (55/88)
Before competition	31.8% (28/88)	20.5% (18/88)	47.7% (42/88)
During competition	35.2% (31/88)	22.7% (20/88)	42.0% (37/88)
After competition	23.9% (21/88)	15.9% (14/88)	60.2% (53/88)

Table 3.7 Athlete reported consumption of sports drinks around training and competition.

4. Discussion

4.1 Study Design

The present study was a descriptive cross-sectional study. The study consisted of a sample of convenience of athletes who consented to participate following distribution of a participant information leaflet through the Sports Ireland Institute (SII). The results of a clinical examination and questionnaire were recorded electronically using open-source software, KoBoToolbox (Kobo Inc, USA).

4.2 Clinical examination

Clinical examination was conducted by two trained and calibrated postgraduate dentists. The findings of the clinical examination were recorded electronically on a data collection form constructed on open-source software, KoBoToolbox (Kobo Inc, USA). Inter-examiner reliability following independent ICDAS training was scored at over 0.9 following independent evaluation using a sequence of 60 images containing different ICDAS scores.

For the clinical examination the following validated indices to evaluate oral health were used; ICDAS II, BEWE, BPE, WHO Trauma and PUFA. These indices were used as they represented evidence-based, validated clinical indices that had already been used in peer-reviewed research involving athletes so that direct comparisons could be made (Needleman et al. 2013). Previous research involving both athletes and the general population have used a range of other measures of recording disease prevalence limiting their comparability (Health and Social Care Information Centre, 2009; Kragt et al. 2019). Following an extensive review of the literature, the indices used were chosen for their validity, reliability and utility in comparison with existing available research data as well as being endorsed by the World Health Organisation for epidemiological research (Gallagher et al. 2018; Frese et al. 2018; WHO 2013).

Since dental caries is a dynamic and complex process, its diagnosis and classification can be challenging. There is a wide range of different indices that evaluate dental caries lesions. The International Caries Detection and Assessment System (ICDAS) has presented a substantial level of reproducibility and accuracy for assessing primary coronal carious lesions and has been used widely used in both clinical and epidemiological studies (Braga et al. 2009; Ekstrand et al. 2018). The advantage of using the ICDAS index is that it allowed the identification of not only cavitated carious lesions, such as with the DMFT index, but also evaluates the wide range of clinical carious lesion presentations such as non cavitated enamel caries lesions, ICDAS 1-2, to more extensive cavitated lesions, ICDAS 4-5 (Braga et al. 2009; Ekstrand et al. 2018; Ismail et al. 2007).

Prior to clinical examination, the teeth needed to be clean (plaque free) and dry, in order to detect the earliest signs of caries (ICDAS 1-2). This was a challenge as the examination was conducted outside a dental setting in the current study. To attempt to mitigate this issue, an LED (Daray x200) mobile overhead light was used to illuminate the field of view. Teeth were then cleaned with gauze and a WHO-probe, which has a ball-point tip, to assist in the identification of microcavitated lesions restricted to enamel (ICDAS 3). The use of the ICDAS II system (two-digit system) allowed the detection not only of primary coronal caries but also historical caries and subsequent dental interventions as it evaluated the presence of restorations, crowns, fissure sealants and temporary restorations (Braga et al. 2009).

The use of ICDAS criteria has been reported previously in studies with elite athletes (Frese et al. 2018; Gallagher et al. 2018). ICDAS II was used in the current study as it allowed a more detailed classification by histological extents of the lesion and its treatment need (Coelho 2020). Whilst it is appreciated that ICDAS II was more complex and time consuming than using DMFT and significant time was required in appropriate training and calibration to use this index appropriately, the benefits of improved sensitivity, specificity, and assessment of lesion severity had been demonstrated previously (Coelho 2020; Ekstrand et al. 2018; Potlia et al. 2016).

In order to compare the findings presented in this study with other data available in the literature that used DMFT as an index for caries evaluation, the number of decayed teeth with a caries diagnostic threshold of ICDAS 4 or greater was used. In addition, the number of restorations and crowns were also considered as corresponding to “filled” teeth from the original WHO index (DMFT). Therefore, it was possible to directly compare results with DMFT values used in previous research (Mendes et al. 2010).

In the current study, the prevalence of dental caries in the athlete population studied was 72.7%, ICDAS 4 or greater. This is much higher than that reported from other studies, where Gallagher and co-workers in 2018 reported a prevalence of 49.1%, where they used a lower caries ICDAS threshold of 3 or more, in an athlete population, and Needleman and co-workers reported a caries prevalence of 55.1% in athletes presenting at the London 2012 Olympic Games, although it is unclear what index was used to define the enamel or dentine caries in that study (Gallagher et al. 2018; Needleman et al. 2013).

There is little recent data published on the caries prevalence of the general Irish population in patients within the same age group as in the present study. However, The Oral Health of Irish Adults 2000-2002 study reported a mean DMFT of 4.9 in healthy (ASA I) individuals aged between 16-24 years old (Whelton et al. 2007). Looking at the data in the current study a mean of 1.75 carious teeth with ICDAS scores of 4 or more and filled teeth (mean of 5.1 teeth per athlete) it can be concluded that the teeth of athletes are in a much poorer condition even when not considering missing teeth than with data for the general Irish population (Whelton et al. 2007).

Further studies are necessary to determine the current oral health status of the general Irish population are needed so direct comparison with subgroups such as the athlete population will be more appropriate in the future.

In addition to caries evaluation, the present study also investigated the prevalence of erosive dental wear in the elite Irish athlete population. Several methods can be used to identify dental erosive wear (Joshi et al. 2016). The index used in the current research that presents with good validity and reproducibility if the Basic Erosive Wear Examination (BEWE) scoring system (Bartlett et al. 2008). The BEWE scoring system used in the current study was a previously validated index to measure dental erosion (Olley et al. 2014). The use of this index in the present study allowed comparisons with previous studies involving athletes (Frese et al. 2015; Gallagher et al. 2018; Kragt et al. 2019; Needleman et al. 2013). The BEWE was a fast and convenient index used with sensitivity and specificity comparable with other indices such as TWI and the Evaluating Index of Dental Erosion (Margaritas et al. 2011). It was appreciated that no one index was ideal in measuring erosion in epidemiological research but the BEWE in the current study allowed for rapid, efficient data collection (Holbrook et al. 2014).

The BPE screening tool was used in the current study to rapidly guide the calibrated examiners to arrive at a provisional diagnosis of periodontal health, irrespective of attachment loss and bone loss (Dietrich et al. 2019). While it is not able to establish a definitive periodontal diagnosis, it is a rapid screening tool well suited to the current study due to its simplicity and efficiency (Dietrich et al. 2019). Researchers have recognised its limitations in patients already diagnosed with periodontitis as staging of periodontitis according the 2017 classification is based on radiographic bone loss or clinical attachments loss which cannot be captured by the BPE (Papapanou et al. 2018). It was considered that due to time constraints a full mouth charting of the periodontal tissues was unfeasible due to the nature of the research and its associated time constraints.

4.3 Study population

Restriction of movement due to the covid pandemic as well as the limited access to this niche population, made access to a sufficient number of athletes that would be representative of a wider range of sporting disciplines difficult. This study examined a total of 89 athletes with full data available for 88 athletes. It is still not clear what led to the loss of data for 1 athlete examined. This research aimed to collect data from as many athletes through the SII as possible. Previous studies have reported on larger athlete population but these were either carried out at Olympic Games events with access to a greater number of athletes by the nature of the competition and the number of athletes present (Needleman et al. 2013; Vougiouklakis et al. 2008; Yang et al. 2011).

However, the number of athletes reported in this study was similar to previous research which involved 116 Dutch from a potential 800 athletes who were eligible for the Rio de Janeiro Olympic and Paralympic Games in 2016 (Kragt et al. 2019). The number of Olympic athletes or prospective Olympic athletes that participated in this study was fifty one. For comparison Ireland only had 77 Olympic athletes and 44 Paralympic athletes (total 121) competing at the same games (McClatchey 2016). Unfortunately, it is unclear due to available records and limited access due to GDPR, how many athletes are currently registered with SII. There were also no Covid 19 restrictions and fewer issues with access to athletes when the study involving the Dutch athletes was undertaken (Kragt et al. 2019). It would be interesting to perform a similar repeat study involving Irish athletes following the Paris 2024 Olympic Games for comparison with the current findings.

4.4 Overview of key findings

High levels of oral disease amongst elite athletes in Ireland were identified. The prevalence of dental caries was 72.7%, dental erosion 19.3%, with 46.6% athletes presenting with gingivitis and 53.4% with periodontitis. In addition, a clear negative impact of oral health on wellness, quality of life, or training and performance was reported by many athletes.

4.5 Comparisons with previous studies involving athletes

4.5.1 Utilisation of Dental Services

Direct comparisons with previous studies were difficult as most reported on dental service utilisation rather than oral health findings. Furthermore, the reported data was often presented as aggregated findings from both athletes and other accredited individuals, and in some cases the latter accounted for nearly half of the treatment provided (Vougiouklakis et al. 2008).
Other researchers looking at similar cohorts have demonstrated a marked trend in increased utilisation of dental services at Olympic Games (Kragt et al. 2019; Needleman et al. 2013; Vougiouklakis et al. 2008; Yang et al. 2011). This may be due to the increasing body of evidence from previous Olympic games creating further awareness and therefore utilisation of such free services at the Olympic games where much of this specific research has been carried out.

4.5.2 Dental Caries

One of the earliest reports on elite athletes was a pilot study conducted on British athletes prior to the 1968 Olympic Games in Mexico City as a well as a survey of other athletes participating at the Games themselves (Forrest 1969). At that time fluoride toothpaste use was uncommon and not readily available. They reported a mean of 3.5 carious teeth among British athletes. The range

observed for other regions competing at the Games went from 1.16 carious teeth (Africa) to 4.5 carious teeth (North America) (Needleman et al. 2013). However, it was unclear which classification system was used in that research (Forrest 1969). The current study on Irish elite athletes reported that athletes had on average 1.75 carious teeth (scoring ICDAS 4 or more) which required intervention.

The reduction in carious teeth per athlete in Ireland when compared with British and North American athletes, when this research was carried out in 1968, is likely down to the availability of fluoridated water supplies, improved access and availability of dental services as well as increased awareness of oral health despite the increase in refined dietary carbohydrates (Newburn 1989). O'Mullane and co-workers demonstrated the clear impact of the introduction of fluoridated water in caries reduction during this time (O'Mullane et al. 1984). In their research they surveyed children in Ireland using the WHO caries criteria of the time pre fluoridation (1961 to 1963) and again in 1984 (O' Mullane et al. 1984). They found a 40% reduction in the mean dmft scores of 5- and 8-year-olds, a 21 % reduction in the DMFT of 12 years old and a 24% reduction in the DMFT of 15-year-olds when comparing the same area pre fluoridation to post fluoridation of the water (O'Mullane et al. 1984).

It is important to appreciate that the Adult Dental Health Surveys from 1968 until 1998 "in order to ensure uniformity of recording with the other examiners, only obvious decay lesions were recorded" (Steele et al. 2012). Prior to the Adult Dental Health Survey in 1998 only overtly cavitated lesions were recorded as carious, therefore it is likely that levels of caries in these previous studies may have underestimated the level of dental caries relative to a modern validated index like the ICDAS (Broadbent and Thomson 2005). Carious lesions had increased significantly since the commercial production of high-fructose corn syrup (HFCS) began in 1967 as well as other commercially refined carbohydrates (Gross et al. 2004).

4.5.3 Periodontal disease

In this current study 71% of athletes presented with signs of gingivitis, (BPE 1,3 or 4), 46.6% with bleeding on probing and no periodontal pockets exceeding 3.5mm or more, (BPE 1 or 2), and 53.4% athletes presented with pocketing indicative of periodontitis, periodontal pocketing exceeding 3.5mm or more, (BPE 3 or 4). No athletes in the current study presented with all sextants scoring a 0.

Gallagher and co-workers reported a prevalence of 77% of athletes scoring a BPE code 1 or 2 (Gallagher et al. 2018). Whereas if the same criteria were used in this study the prevalence would have been 96.6%. Gallagher and co-workers also found a prevalence of 21.6% of athletes scoring a BPE of at least 3 or 4, whereas the data from the current study showed a prevalence of 53.4% (Gallagher et al. 2018). Gallagher's and co-workers findings in 2018 were similar to findings

presented by Needleman et al. in relation to the London 2012 Olympic Games (Gallagher et al. 2018; Needleman et al. 2013). Needleman presented data of 76% of athletes presenting with BPE scores of 1 or 2, and 15% of athletes scoring BPE scores of 3 or 4 (Needleman et al. 2013).
The higher prevalence of periodontal problems presented in the current study may have been due to a number of factors such as different sport modalities, where a significant proportion regularly used a gum shield (29.5%) as well as the data for the majority of athletes being recorded around training schedules, potentially increasing vasodilation and general inflammation from the physical activities performed prior to scheduled examination.

4.5.4 Erosion

A study involving German young athletes evaluated the prevalence of dental erosion and presented data to show that the risk of erosive wear was low with a cumulative BEWE score of 3.6 in their 88 competitive athletes (Merle et al. 2022). In contrast to these findings, Gallagher and co-workers demonstrated that in their UK athlete population that 49.1% of athletes reported a cumulative BEWE score of 7 or more (Gallagher et al. 2018). In the current study athletes who scored 7 or more using the BEWE scoring was 9.1% and 6 or more was 18.2 %. Factors that may have influenced the results are the type of sports that participants were involved in and their associated recommended dietary intake as well as the consistency of food and beverages to facilitate their training and performance. For example, cyclists frequently use foods and beverages such as energy gels to consume while training on the bike, as this method of carbohydrate delivery is more convenient for the physical activity (Saunders et al. 2007). In the study on young German athletes, the majority of participants were runners or biathletes (Merle et al. 2022). Gallagher and co-workers studied endurance sports and rugby players in their studies (Gallagher et al. 2018). While in the present study the athletes were mainly cricketers, boxers and rowers. Each sport has their own training routine, energy requirements and particular dietary methods of consumption, and this can have different impacts on oral health findings (Khan et al. 2022).

4.5.6 Trauma and PUFA

Just one athlete (1.1%) had “at least one PUFA finding”, of which they had one, in the current study. Higher numbers of athletes have presented with at least one PUFA finding in previous studies examining athletes (Gallagher et al. 2018; Needleman et al. 2016). These studies reported a prevalence of at least one PUFA finding 3.4% and 7.8% respectively (Gallagher et al. 2018; Needleman et al. 2016). The low prevalence of PUFA demonstrated in the current cohort may be down to the smaller sample size compared with the studies conducted by Needleman and co-workers (Needleman et al. 2016). The lower prevalence may also be as a result of Irish athletes being required to train and compete with appropriate mouthguards in place when boxing, where

a large number of athletes were boxers (22/88) and the use of mouthguards was greater, with 26 of 88 athletes and four cricketers using mouthguards to reduce the impact of potential dental trauma in their sport.

Data from the London 2012 Olympic Games reported that 17.6% of athletes attending reporting new trauma (Needleman et al. 2013). This higher prevalence at the London 2012 Olympic Games may have been due to selection bias as athletes with known problems were more likely to attend the polyclinic at the Games opportunistically to seek treatment (Needleman et al. 2013).

4.5.7 Performance and Wellbeing

Previous studies have also reported adverse impacts on the well-being and performance of athletes. Researchers at the London 2012 Olympic Games reported a higher impact on training and performance (18%) compared to the current research findings, where only 10.2% of athletes reported an impact on their training and performance as a result of their oral health (Needleman et al. 2013). However, this might have reflected the reduced changes in perception relative to the enormous impact that Covid 19 had on training and performance during the pandemic (Patel et al. 2022). This was demonstrated in reports from coaches of gymnasts in the UK reporting their opinions on the perceived impacts of the Covid pandemic on training performance and potential for injury. The consensus opinion was that the burden of the pandemic was the greatest barrier to training and performance (Patel et al. 2022).

The methods used for assessing performance impacts were identical to previous research (Needleman et al. 2013). It was appreciated that this simple tool of three questions may lack the necessary sensitivity to identify effects, and the true impacts may well be higher (Wong et al. 2002). In retrospect, alternative methods of assessing such impacts using interviews or focus groups may be worthwhile consideration for future studies, as the limited time available to examine and interview athletes alongside their busy training and performance schedules precluded longer evaluations (Gill et al. 2008).

It was therefore appropriate that this study used a combination of the 4-item Oslo questionnaire as well as questions presented by research from the Eastman Dental Institute to attempt to further describe the effects on performance and wellbeing (Needleman et al. 2016). In that study they reported that of the 187 UK professional male football players interviewed, 20% reported an impact on their quality of life and 7% on training and performance (Needleman et al. 2016).

4.5.8 Athlete perception of general health and oral health

In the current study, 96.6% of athletes assessed their general health as very good or good, but only 67% assessed their oral health as very good or good. These findings are similar to results published in an earlier study by Gallagher and co-workers, where they found that 90% of athletes

assessed their general health as very good or good, but only 69.2% assessed their oral health as very good or good (Gallagher et al. 2018). Both Irish athletes and UK athletes have similar perceptions of their general and oral health which may also support the societal and cultural similarities between the UK and Ireland.

4.6 Comparison with previous studies involving the general population

It was not possible to recruit a control population specific to this study. However, the Adult Dental Health Survey (2009) where the population of Northern Ireland was last included as part of this United Kingdom survey provided data from clearly defined age categories. This data therefore is the most relevant general population study and applicable to compare with data from Irish elite athletes. Due to the nature of the clearly defined criteria, it is possible to make cautious comparisons between this group of athletes and a group of similar age, 16-24 years and 25-34 years) studied in the Northern Irish population as part of the Adult Dental Health Survey in 2009 (Social Care Information Centre 2009).

Recent data on the current oral health of the general population of Ireland is not available. The last dental health survey in RoI was published in 2007 and based on findings of the population between 2000-2002 (Whelton et al. 2007). However, there is recently published research that was conducted on the general population in England from 2021 (Health and Social Care Information Centre 2023). However, comparison with the Irish athlete population in this study should be undertaken with caution, primarily due to differences in water fluoridation.

The most recent large-scale research looking at the oral health of the general population of Northern Ireland was conducted in 2009 as part of the Adult Dental Health Survey (Health and Social Care Information Centre, 2009). It is important to note that the Adult Dental Health Survey involved participants 16 years of age or older whereas our current research involved participants of at least 18 years of age, where the youngest participant was 18 years of age and eldest was 53 years of age (range 18-53).

4.6.1 Number of natural teeth (general population)

In the study on the Northern Irish population, it was reported that participants had a mean of 25.1 natural teeth present whereas the population in the age range 25-34 had 27.5 natural teeth present. Athletes in the current study presented with a mean of 30.1 natural teeth. The percentage of the Northern Irish population that had 18 or more sound untreated teeth were 39% for the entire population and 57% of the population aged between 25-34. In the current study of athletes 94.3% of athletes had 18 or more sound untreated teeth.

4.6.2 Dental Caries

In the Adult Dental Health Survey, it was reported that 28% of dentate adults had carious teeth (Health and Social Care Information Centre, 2009). Whereas in the current study population 72.7% of athletes presented with caries, scoring ICDAS 4 or more. The findings of the current study are much higher than what was found in the Northern Irish population in 2009. This may be a result of the dietary patterns and nutrient intake of athletes to facilitate training and performance being more cariogenic (Tripodi et al. 2021).

On the other hand, the number of natural teeth present in the Northern Irish population is lower, which is possibly a result of premature extractions due to extensive caries, where restorative intervention would have sufficed. Athletes in this study presented with more natural teeth on examination and therefore have a greater number of surfaces that could potentially develop caries.

4.6.2 Periodontal disease

In the Adult Dental Health Survey 64% of the Northern Irish general population presented with bleeding on probing, in the current study, 80.7% of athletes presented with bleeding on probing (BPE score 1). This may be a result of a greater proportion of mouth breathing due to physical exercise (Gulati, Grewal and Kaur 1998). However, a recent systematic review and meta-analysis found that physical activity was a potential tool for reduction in periodontal disease prevalence (Ferreira et al. 2019).

4.6.3 Erosion

In the current study dental erosion was present in 19.3% athletes whereas in the Northern Irish population (Adult Dental Health Survey 2009) there was “moderate wear” in 15% (Health and Social Care Information Centre, 2009). In the Adult Dental Health Survey, 2009, the prevalence of wear was reported and outlined at three thresholds; “any wear, wear that has exposed a large area of dentine on any surface (moderate wear) and wear that has exposed the pulp or secondary dentine (severe wear)” (Health and Social Care Information Centre, 2009). Therefore, findings were not directly comparable to the current study of elite athletes in which the validated BEWE index was used (Ganss et al. 2011).

4.6.4 Number of restored teeth

In the current athlete study, athletes presented with a mean of 5.1 restored teeth which is lower than the average of 7.3 restored teeth per person from Northern Ireland in the Adult Dental Health Survey (Health and Social Care Information Centre, 2009).

4.6.5 Social history (smoking)

Just 10.2% of athletes in the current study population reported previous or current use of tobacco, whereas as high as 25% of the Northern Irish population reported to be smokers of tobacco (Health and Social Care Information Centre, 2009).

4.6.7 Preventative behaviour

In this study, 96.6% of athletes reported cleaning their teeth twice per day, whereas only seventy-five per cent of the Northern Irish dentate population said they cleaned twice a day. In total, 96% of the general population studied in the Adult Dental Health Survey reported using a fluoride containing toothpaste, whereas 98.9% of athletes reported using fluoridated toothpaste. In this study, 54.5% of athletes reported using a powered tooth brush compared to just 14% of the general population of Northern Ireland examined in the Adult Dental Health Survey (Health and Social Care Information Centre 2009). In total, 48.9% of athletes reported using interdental aids versus 17% reported in the Adult Dental Health Survey (Health and Social Care Information Centre 2009).

4.6.8 Potential reasons for differences between athletes studied and general population

The prevalence of caries found in the current elite athlete population (72.7%) was higher than found in a similar UK population, which reported a caries prevalence of 55.1% using the same criteria (Needleman et al. 2013). It is clear from previous research that caries risk and disease levels have repeatedly been demonstrated to be higher in athletes as a result of frequent carbohydrate intake and reduced salivary flow (Mulic et al. 2012). Despite this high incidence of caries demonstrated among the current athlete sample, fluoride toothpaste use was high at 98.9% but interdental cleaning aid use and sugar free chewing gum use was much less at 48.9% and 42% respectively.

A recent systematic review published in the Cochrane Library which compared caries incidence and the use of interdental cleaning devices with toothbrushing and toothbrushing alone actually included no studies that assessed caries as an outcome (Worthington et al. 2019). However, they did demonstrate, with a low level of evidence, that plaque and bleeding scores were reduced with the use of interdental cleaning aids (Worthington et al. 2019). Another study using cross-sectional data from the Korean National Health and Nutritional Examination Survey found that “non-flossers” had a 1.46 times higher risk of proximal caries than flossers (Kim et al. 2021). However, they found this association to be strongest for those aged in their 40’s and may not be as applicable to the athletes participating in this study with a mean age of 25.6 years (Kim et al. 2021).

In contrast to interdental aids, it appears there is stronger evidence to demonstrate a lower incidence of caries in those who chew sugar-free gum compared with non-chewing controls in a recently published systematic review and meta-analysis (Newton et al. 2019). From the twelve studies reviewed in this meta-analysis the intervention of chewing sugar-free gum was found to significantly reduce caries increment, giving a preventative fraction of 28%>. It is noteworthy that in the 8 trials that used xylitol gum only as the basis of intervention, the preventative fraction was 33% (Newton et al. 2019).

The higher caries incidence may also be due to the variations in health service provision in Northern Ireland where athletes' resident there relayed difficulties in organising treatment or dental examinations. Of the 15 athletes permanently resident in Northern Ireland, a third of these had not had a dental check-up in over a year and 20.0% of the Northern Irish athletes had not seen a dentist in over 2 years. It had been previously been reported by the Adult Dental Health Survey, carried out in 2009, that 15% of people aged 25-34 in Northern Ireland had not had a dental check-up in over 2 years and 30% had not had a dental examination in over a year (Health and Social Care Information 2009).

These results were similar for athletes residing in the Republic of Ireland, where 30.1% of athletes had not received a check-up in over a year and 13.7% of athletes had not seen a dentist in over two years. The RoI based athletes expressed concerns over the high costs associated with treatment and dental examinations as a major barrier. Rather than access to care, the RoI based athletes did not seek dental care as a result of the financial burden relative to the salaries they obtained from their sporting discipline alone.

However, it is important to note the impact that Covid 19 government-imposed restrictions had on dental service provision in both Northern Ireland and the Republic of Ireland during this time and the preceding two years. For much of the time in question, service provision Ireland and the United Kingdom was either non-existent, emergency only or dealing with the backlog of existing treatment plans (Stennett and Tsakos 2022).

Additionally, periodontal disease is another oral health condition that has been associated with negative impacts on quality of life in general populations (Needleman et al. 2004). The current study demonstrated gingivitis with no pocketing in 46.6% athletes, as defined by a basic periodontal examination code of 1 or 2. However, athletes presenting with either a code of 1, 3 or 4 was as high as 89.8% of athletes which demonstrated an absence of good periodontal health in a high proportion of athletes.

Use of the basic periodontal examination (BPE) ensured direct comparison could be made with previous research conducted at the 2012 Olympic games where they demonstrated a similar incidence of gingivitis at 76%. The current study findings may have been influenced by the use of nicotine containing electronic cigarettes, where in our research 10.2% of athletes admitted to

current use or previous use. It has been previously demonstrated that electronic cigarette use led to greater habitual frequency of intake than cigarette use and can carry greater concentrations of nicotine leading to higher serum concentration of nicotine in the user (Goldenson et al. 2017). This may have reduced the number of sites with bleeding on probing, effectively masking and reducing the incidence of gingivitis observed (Heasman et al. 2006). It was also noted during questioning that some athletes did not wish to declare that they used electronic cigarettes despite having them on their person. Therefore, the use of electronic cigarettes may well be much higher than reported.

Interestingly dental erosion in athletes was found to be lower, at 19.3%, than previous research conducted which reported an incidence of as high as 44.6% in athletes (Needleman et al. 2013). There appears to be greater awareness of the detrimental oral health effects of sports drinks and fizzy drinks currently as reported in a cross-sectional questionnaire survey of 160 school children in south Wales (Fairchild et al. 2017). In that study it was reported that around half of schoolchildren, aged 12-14 years, were aware that dental erosion may result from sports and fizzy drink consumption, and approximately two thirds knew that they were linked to dental caries (Fairchild et al. 2017).

In a study which utilised focus groups to determine children and young people's perceptions of energy drinks in the United Kingdom found that they had good awareness of the erosive potential of these beverages by using the constant comparative approach (Visram et al. 2017). To date there has been no research comparing the changes in attitudes and awareness of the general population to the erosive damage of fizzy drinks over the last ten years, but may be the case anecdotally (Schlueter and Luka 2018; Sezer et al. 2022).

In the current study, 47.7% of athletes rarely or never consumed non diet fizzy drinks and 35.2% rarely or never consumed diet fizzy drinks. In contrast, 21.6% of athletes consumed non diet fizzy drinks over 3 times a week and 23.9% of athletes consumed diet fizzy drinks over 3 times a week. Over half of the athletes claimed to "never" consume sports drinks around training or competition. There certainly appears to be a shift in attitudes towards these potentially erosive beverages over the last 10 years since another similar research was published (Schlueter and Luka 2018; Sezer et al. 2022).

4.7 Strengths

The strengths of this research include the number of athletes examined, the comprehensiveness of the oral health assessment and the inclusion of self-reported impacts. Data was collected for 88 athletes which was acceptable given the population of athletes in Ireland when compared to previous studies that have a much larger potential athlete population, such as studies conducted

at the Olympic Games or studies involving nations with much larger general populations (Kragt et al. 2019; Needleman et al. 2013; Vougiouklakis et al. 2008; Yang et al. 2011).

Despite the loss of data for one participant, data collection methods for the 88 athletes were rigorous and well-planned, and provided data which was reliable. This study also ensured the use of well-defined variables and validated clinical indices for measurement of oral diseases where the researchers conducting the examination had appropriate training and calibration. This study also adhered to the gold standard ethical considerations set out by the Faculty of Health Sciences Research Ethics Committee at Trinity College Dublin, ensured informed consent, and protection of participants privacy. In addition, the methodology is clearly described and in keeping with previous studies involving elite athletes presented. This will allow for future researchers to more easily replicate this study's methodology and build on existing data.

4.8 Limitations

The limitations included the select nature of the sample, as all the athletes examined were those that voluntarily chose to attend after receiving the participant information leaflet. There were also some athletes invited to participate in the study that did not attend due to training and competition commitments and Covid-19 restrictions. There may also have been biases in the athletes who attended might have knowingly had perceived poorer oral health and were therefore more eager to attend the free clinical examination. Therefore, the results recorded may not represent the oral health of all elite athletes in Ireland. It may also have been the case whereby some athletes who were aware of the severity of their dental health problems not attending through embarrassment or avoidance as they did not wish for their data to be included in this study, introducing selection bias (Gilbert et al. 1997).

Indices such as the WHO Trauma index relied on self-reported data from patients which may have introduced recall bias. Because of the nature of the study, it has proven difficult to follow up the same athletes over a longer period of time due to the nature and short career in some instances of being an athlete at elite level (Wylleman and Reints 2010). As is the case with observational studies it is difficult to control variables and establish cause and effect. It is also difficult to compare data with controls as there are no recent studies measuring the oral health of the general population in Ireland available.

However, it is also important to realise that pain and oral health problems were not factors in these athletes choosing to attend as it was made clear that no treatment could would be provided. Therefore, attendance of the athletes was not a reflection of their oral symptoms or disease prevalence. It is acknowledged that to achieve a full understanding of oral health conditions, an epidemiological study of a representative sample of athletes is indicated.

4.9 Critique of existing data and recommendations for future studies

4.9.1 Summary of previous research

The poor oral health identified in athletes in this study is certainly not a new finding (Bryant et al. 2011; Forrest 1969; Gay-Escoda et al. 2011; Needleman et al. 2013). Research undertaken at Olympic Games events and in different sports teams have continued to demonstrate poor oral health in athletes irrespective of where the research has been completed (Bryant et al. 2011; Needleman et al. 2013; Vougiouklakis et al. 2008; Yang et al. 2011). It is however clear that the most prevalent problems of dental caries, erosion and periodontal diseases are preventable (Petersen 2003). The long-term effect of poor oral health on these athletes in later life is unknown. If these oral diseases are not appropriately managed and appropriate treatment provided then they could have a considerable future impact on the athletes. Some of these impacts include a high treatment need, increased tooth loss, reduced capacity to function and negative psychological effects (Needleman et al. 2013). Prevention of oral diseases and promotion of oral health education should therefore become an essential part of overall care and training of elite athletes. Such preventative programmes can be simple to establish, however issues surrounding the responsibility for their funding and implementation have been shown to be a barrier to their initiation (Petersen and Kwan 2011).

4.9.2 Summary of current findings

The impact of oral health on training and performance was clear in the current study was clear. Years of sacrifice, commitment and training could potentially be compromised by common and entirely preventable conditions (Petersen 2003). This is concerning as all of the participating athletes expressed that their mouth teeth or gums had negatively impacted them in some way. Sport can be a game of inches or seconds and these detrimental impacts to training, performance and competition can result in reduced performance leading to poorer outcomes (Cardoso et al. 2023). Despite this, the current study demonstrated decreased levels of perceived impact on training and performance compared to previous studies at the Olympic Games (Needleman et al. 2013; Vougiouklakis et al. 2008; Yang et al. 2011).

4.9.3 Effect of covid pandemic

It is important to note that perception and recall of events can change based on the environment. (Coughlin 1990). The elite athletes in this study were outside of a competition environment, which in addition to the impact of Covid 19 restrictions could potentially obscure the perceived impact of their oral health problems. This was evident when Biggins and co-workers compared

the health and well-being of sixty-five elite international athletes before during and after international competition (Biggins et al. 2020). They found that general health and well-being was poorer during competition when evaluation was carried out using health (Subjective Health Complaints Inventory) and well-being (Sports Profile of Mood States) questionnaires (Biggins et al. 2020). “The possibility of an athlete losing four hard years of training due to an avoidable dental illness or injury is unacceptable and steps must be taken to prevent these occurrences” (Piccininni and Fraser 2005). The data from the present study strengthen the recommendations of the 2009 IOC statement “…further studies are required to assess more accurately the oral health of the athlete population, and educational programmes should be expanded and targeted to those sports where the risks identified above influence athlete health…The IOC group encourages athletes to be provided with regular dental examinations” (Ljungqvist et al. 2009).

4.9.4 Recommended future health promotion

Oral health programmes for athletes should utilise available existing local resources with an emphasis on oral health promotion and education on prevention. Moreover, there is a need for regular assessment of an athlete’s oral health leading to an appropriate and individualised preventative programme depending on their risk and presenting dental problems. Indeed, this could be facilitated by integrating oral health within sports medicine or establishing and promoting roles for a sports dentist (Gallagher et al. 2021). Through integrating dentists as members of the athlete support team, dentist could provide sport-specific oral health advice, encouraging athletes to take responsibility for their oral health. Through encouraging and promoting these roles for health professionals it might ensure that appropriate best-evidence advice and treatment will be available for athletes and will help further develop research and clinical knowledge in the field.

4.9.5 Future research

Future research should include more detailed epidemiological studies in Irish athletes of oral health and its impact on training and performance by capturing a more representative sample of elite athletes. This data could then help shape and guide the development of more appropriate oral health strategies for athletes. Differences in oral health may well be expected between different sports and different countries where different diets, attitudes and access to healthcare exist (Northridge et al. 2020). This necessitates an international approach and collaboration is necessary to facilitate such research. One programme idea would be to widen the focus beyond the oral health perception and behaviour of the athletes, and include, the wider training team, i.e., coaches, nutritionists and chefs. Further research may then be able to guide improved dietary

practices that do not have such a detrimental effect on oral health as well as inform improved formulations of sports drinks and supplements.

It would also be beneficial to observe this population over an extended period. This would enable researchers to identify trends in oral health patterns over time. Through studying these trends, it would enable researchers to more accurately identify the prevalence of oral health diseases in this population. Longitudinal research can also better examine the long-term effects of lifestyle and dietary habits, helping to identify potential risk factors and inform preventative strategies. In studying athletes over a greater period of time, researchers could assess the effectiveness of different oral health interventions and treatments. This could then lead to the development of tailored prevention and treatment strategies for athletes. Longitudinal research would also be best suited to identify cause and effect relationships compared to cross sectional studies such as undertaken in this study. This would enable greater understanding of whether a specific aspect of an athlete's lifestyle or training may be causing oral health issues. Over time, longitudinal studies, may identify specific risk factors for oral health issues among athletes. This may then help inform and improve development of policies, guidelines and preventative strategies in promoting improved oral health among athletes.

This study has identified a clear need for properly integrated oral healthcare care pathways, preventative education, and services for the Irish elite athlete population. Given these findings it is also hoped that further research can be shaped to explore the oral health of elite athletes at a larger scale given the ending of the Covid 19 pandemic. Further research may also look to include more details on specific dietary intake through more detailed dietary assessments of the athletes that can be compared with their oral health status. It is hoped that further research and education can improve the oral health and quality of life of elite athletes to improve their overall health and well-being. Effective implementation of such services may act as a platform for access to amateur athletes through schools, local community services and local sports clubs to improve the overall health and awareness of the general population.

5. Conclusions

This descriptive cross-sectional study consisted of a convenience sample of 88 elite athletes across two training facilities across Ireland. The primary aim of the research was to explore and collect data on the prevalence of oral disease, dietary information, and assess the impact of the effect of oral health on sports performance and participation in an elite athlete population was achieved.

This study demonstrated that there was a high prevalence of caries (72.7%) with an average of 1.75 teeth per athlete requiring restorative intervention. In addition, 19.3% of athletes presented with dental erosion and a high proportion of athletes presented with periodontal issues (gingivitis only 46.6%, periodontitis 53.4%).

In total, 39.8% of athletes of athletes had experienced pain from their mouth, teeth or gums in the last 12 months. Moreover 27% of athletes expressed that their oral health had impacted on their quality of life. Interestingly nearly all athletes rated their general health as good or very good (96.6%), which was a much greater proportion than for their oral health, where only 67% of athletes rated their oral health as good or very good.

It is hoped that the current study may act as a catalyst for future research into and education of the sporting community highlighting the importance of attaining and maintaining oral health in Irish athletes.

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7. Appendix

Appendix 1: Ethical Approval Letter

Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

Dr Jo Saele,
Dublin Dental Hospital,
Lincoln Place,
D02 F859

15th December 2021

Ref: 210910
Title of Study: Oral health of elite athletes in Ireland

Dear Dr Saele,

Further to a meeting of the Faculty of Health Sciences Ethics Committee held in December 2021. We are pleased to inform you that the above project has ethical approval to proceed.

This study has been ethically approved. We would advise you to seek review and comments on your DPIA from the DPO if required prior to study commencement'

As a researcher you must ensure that you comply with other relevant regulations, including DATA PROTECTION and HEALTH AND SAFETY.

Yours sincerely,

Prof. Jacintha O'Sullivan
Chairperson
Faculty Research Ethics Committee

Dámh na nEolaíochtaí Sláinte
Foirgneamh na Ceimice,
Coláiste na Tríonóide,
Ollscoil Átha Cliath,
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Appendix 2: Participant Information Leaflet

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

DUBLIN DENTAL UNIVERSITY HOSPITAL
OSPIDÉAL DÉADAIGH OLLSCOILE ÁTHA CLIATH

Participant Information Leaflet

Name of Study: Oral health of elite athletes in Ireland.

Site	**Institute of sport Ireland**
Principal Investigator(s) and Co-Investigator(s)	**Dr. Michael O'Sullivan: michael.o'sullivan@dental.tcd.ie** **Dr. Lewis Winning:** lewis.winning@dental.tcd.ie **Dr. Michael Crowe:** mc@gcdental.ie **Dr. Jo Saele:** jo.saele@dental.tcd.ie **Dr. Annie Hughes:** AnnieMargaret.Hughes@dental.tcd.ie **Dr. Sharon Madigan:** smadigan@instituteofsport.ie **Dr Brendan Egan:** brendan.egan@dcu.ie
Study Organiser/ Sponsor (if applicable)	**N/A**
Data Controller	**Trinity College Dublin**
Data Protection Officer	**Data Protection Officer** **Secretary's Office** **Trinity College Dublin** **Dublin 2**

You are being invited to take part in a research study that is being done by Dr. Jo Saele and his research team at Institute of Irish Sport.

Before you decide whether or not you wish to take part, please read this information sheet carefully. Ask Dr Jo Saele or any of the investigators named above any questions. Don't feel rushed or under pressure to make a quick decision. You should understand the risks and benefits of taking part in this study so that you can make a decision that is right for you. You may wish to discuss it with your family, friends or GP.

This leaflet has five main parts:

Part 1 – The Study
Part 2 – Data Protection
Part 3 – Costs, Funding and Approval
Part 4 – Future Research
Part 5 – Further Information

1

Part 1: The Study: Oral health of Elite Athletes in Ireland

Why is this study being done?

Previous studies)[1] *at the London 2012 Olympics found a high incidence of oral disease amongst elite athletes which affected their sporting performance.*

We wish to evaluate the oral health of elite athletes in Ireland. to see if there are any similar trends and how this might impact sporting performance.

The study will have the potential to positively influence government policies for future generations of athletes across Ireland.

Why have I been invited to take part?

- *You have been identified as an Irish elite athlete.*
- *We are looking for elite athletes competing in Ireland within certain sporting disciplines to participate.*

Do I have to take part?

You don't have to take part in this study. It is entirely voluntary. If you decide not to take part it won't affect your current or future medical care or your participation/selection in your chosen sport.

What happens if I change my mind?

You can change your mind at any time by contacting your study Doctor at jo.saele@dental.tcd.ie.

If you choose not to continue to take part, this will not affect your participation in Sport Ireland Institute programs in any way.

If you wish, you can ask for your data stored to be destroyed. If you request this, we will destroy all data that are still in our possession.

[1] *Ref: Needleman, I., et al. 2013. Oral health and impact on performance of athletes participating in the London 2012 Olympic Games: a cross-sectional study. British journal of sports medicine.*

We will no longer use data for research from this point onwards.

How will the study be carried out?

- WHEN: The study will take place at a time that works around you so that it has the least impact on your training and competition schedule.
- WHERE: The study will take place at your local team/training centre i.e., Sport Ireland Institute.
- WHAT: You will be asked to have a basic oral health assessment and fill out an online questionnaire.
- HOW MANY: We hope to have around 100 participants enrolled in the study.

What will happen to me if I decide to take part?

We will look to arrange for the basic oral health examination and explanation of an online food consumption questionnaire at a local training centre that is least disruptive to your training and competition schedule. You will be expected to attend one session in person where the basic oral health examination will take place and you will be given sufficient help and information to be able to accurately complete the online questionnaire. All participants will receive the same level and standard of oral health examination. The oral health examination is a basic and routine non-invasive procedure. From this examination we will be able to highlight and inform you of any problems that require attention and further treatment. The examination is provided free of charge to you.

What will happen to information about me (personal data)?

- Data will be collected and stored confidentially in accordance with data protection law
- Your data will be stored on a secure online platform (AWS) that complies with current GDPR European regulations.
- An appointed member of the research team will help keep your data secure. AWS has built in software encryption and firewalls to help prevent loss of your data.
- It will be necessary to retain the Consent Form (personal data) until the research project has been completed and data has been destroyed. This is to provide evidence of consent in accordance with Health Research regulations. However, this personal information will only be available to the lead investigators; Dr Jo Saele, Dr Michael O'Sullivan and Dr Annie Hughes.

Are there any benefits to taking part in this research?

- The main benefit to you taking part in this study is the free basic oral health assessment where we can identify and diagnose disease that could potentially negatively affect your training or athletic performance.

Are there any risks to me or others if I take part?

- ***Basic oral health examination:*** *Some people find a basic oral health examination to be psychologically and physically uncomfortable. It is important that you are comfortable having a basic oral health examination and you are happy for this to be carried out.*
- ***Health Information (Data):*** *There is a risk that a connection to your identity could be made. Great care will be taken to ensure the confidentiality of all data and the risk to participants of a breach of confidentiality is considered very low.*

Will I be told the outcome of the study? Will I be told the results of any tests or investigations performed as part of this study that relate to me?

- *Any outcome from the research that would impact directly or indirectly on the participant's health will be reported to him/her. Information on where to gain appropriate treatment for any diagnosis of oral pathology will be given to the participant. Results of the study will be reported in medical/scientific journals and disclosed at medical/scientific conferences. No information which reveals your identity will be disclosed as data will be pseudonymised.*

Part 2 – Data Protection

What information about me (personal data) will be used as part of this study? Will my medical records be accessed?

This study will have 2 elements of data collection:

- *The basic oral health examination where we will assess you for tooth decay, gum disease and tooth wear.*
- *Online questionnaire asking about your diet and any effect your oral health may have had on your training and performance.*

What will happen to the information about me?

- Arrangements are in place so that personal data will be coded (your name is replaced with a code number so that the information cannot be directly linked back to you).
- Coded research data will be kept for 7 years, and then destroyed in line with current research policy.
- All research data will be stored in accordance with current GDPR rules and regulations.

Who will access and use information about me?

- The following individuals will have access to the information you provide, or information taken from your dental examination (your personal data): Dr Jo Saele, Dr Annie Hughes, & Dr Michael O'Sullivan.
- Data collected is for research conducted and Trinity College Dublin.

Will my personal data be kept confidential? How will my data be kept safe?

- *We use third party cloud-based software AWS (amazon web services) with built in security and firewall features.*
- *We comply with national and European data protection law.*
- *We have carried out risk assessments to help reduce the risk of data breach and ensure the identity of the participants is not disclosed nor are they identifiable during presentation or publication.*

- *Researchers involved with this study are bound by a professional code of secrecy and confidentiality within their profession; this would mean disciplinary action for employees/researchers who disclose or facilitate unauthorised access to your personal data.*
- *All researchers have undergone up to date training in data protection law and current GDPR guidelines.*

What is the lawful basis to use my personal data?

This is scientific research[2] (in the public interest[3]).

We will also ask for your explicit consent to take part in this project, as a requirement of the Irish Health Research Regulations.

What are my rights?

You are entitled to request the following rights, unless it would seriously impact the objectives of the research (for example, if the data were about to be published, and had already been pooled for analysis with other data).

- *The right to access to your data and receive a copy of it;*
- *The right to restrict or object to processing of your data;*
- *The right to object to any further processing of the information we hold about you (except where it is de-identified);*
- *The right to have inaccurate information about you corrected or deleted;*
- *The right to receive your data in a portable format and to have it transferred to another data controller*
- *The right to request deletion of your data*

. You can exercise these rights by contacting your study Doctor Dr Jo Saele at jo.saele@dental.tcd.ie or the Trinity College Data Protection Officer, Secretary's Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie. Website: www.tcd.ie/privacy.

[2] *Article 9(2) (j))*
[3] *(Article 6(1)(e)*

Part 3 – Costs, Funding and Approval

Has this study been approved by a research ethics committee?

This research has been approved by Trinity college Dublin's "Faculty of health sciences research ethics level 2".

Who is organising and funding this study? Will the results be used for commercial purposes?

Research is being conducted by faculty and postgraduate students in tertiary educational settings in Ireland; Trinity College Dublin, University college Dublin and Dublin City University. No funding or grants have as of yet been received or applied for. We do not intend to disclose the results for commercial purposes. However, this research does form part of a postgraduate thesis which is required in them obtaining their academic qualification.

Is there any payment for taking part? Will it cost me anything if I agree to take part?

No, we are not paying patients to take part in the study. Neither will you be charged to participate in this study.

Part 4 – Future Research

Will my personal data and/or biological material be used in future studies?

No. On completion of the study, your personal data will destroyed. This may be up to a maximum retention period of 7 years in line with current research policy.

Part 5 – Further Information

Who should I contact for information or complaints?

If you have any concerns or questions, you can contact:

- *Principal Investigators: Dr Jo Saele jo.saele@dental.tcd.ie or Dr Michael O'Sullivan michael.o'sullivan@dental.tcd.ie or Dr Annie Hughes anniemargaret.hughes@dental.tcd.ie*
- *Data Protection Officer of Dublin Dental hospital: dataprotection@dental.tcd.ie*
- *Data Protection Officer, Trinity College Dublin: Data Protection Officer, Secretary's Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie. Website: www.tcd.ie/privacy.*

Under GDPR, if you are not satisfied with how your data is being processed, you have the right to lodge a complaint with the Office of the Data Protection Commission, 21 Fitzwilliam Square South, Dublin 2, Ireland. Website: www.dataprotection.ie.

Will I be contacted again?

The study is a one-off examination of oral health and dietary assessment. As such there is no further follow up or repeat examination as part of this study.

If you would like to take part in this study, you will be asked to sign the Consent Form on the next page. You will be given a copy of this information leaflet and the signed Consent Form to keep.

Appendix 3: Consent form

Consent form

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

STUDY NAME: Oral health of elite athletes in Ireland.
Centre ID:
Identification Number for study:

Consent Form

There are two sections in this form. Each section has a statement and asks you to tick the box if you agree. The end of this form is for the researchers to complete. Please ask any questions you may have when reading each of the statements. Thank you for participating. Please Tick the box if you agree with the statement. Please feel free to ask questions if there is something you do not understand.

General	Tick box
I confirm I have read and understood the **Information Leaflet** for the above study. The information has been fully explained to me and I have been able to ask questions, all of which have been answered to my satisfaction.	
I understand that this study **is entirely voluntary, and if I decide that I do not want to take part, I can stop taking part in this study at any time without giving a reason.** I understand that deciding not to take part will not affect my future medical care.	
I understand that I **will not be paid for taking part in this study**[1].	
I know how to contact the research team if I need to.	

[1] Amend as appropriate.

I agree to take part in this research study having been fully informed of the **risks, benefits and alternatives** which are set out in full in the information leaflet which I have been provided with.	
Data processing	**Tick box**
I understand that personal information about me (in a coded, deidentified format) will be stored on a secure online platform (Amazon Web Services, AWS). This includes transfer of personal information outside of the EU. I consent to the storage of this data by AWS outside of the EU.	
I give permission for information about me (personal data) to be stored until the study is complete, (no longer than 7 years).	

Patient Name (Block Capitals) Patient Signature Date

Witness Name (Block Capitals) Witness Signature Date

To be completed by the Principal Investigator or nominee.

I, the undersigned, have taken the time to fully explain to the above patient the nature and purpose of this study in a way that they could understand. I have explained the risks and possible benefits involved. I have invited them to ask questions on any aspect of the study that concerned them.

I have given a copy of the information leaflet and consent form to the participant with contacts of the study team

Researcher name

Title and qualifications

Signature

Date

Appendix 4: Screenshots of KoboToolbox digital data collection form

The following screenshot images are of the final digital data collection form used in the study. The digital data collection form was constructed using KoBoToolbox software which was compatible with both computer and the tablets (iPad 9th Generation 64Gb) used in the study.

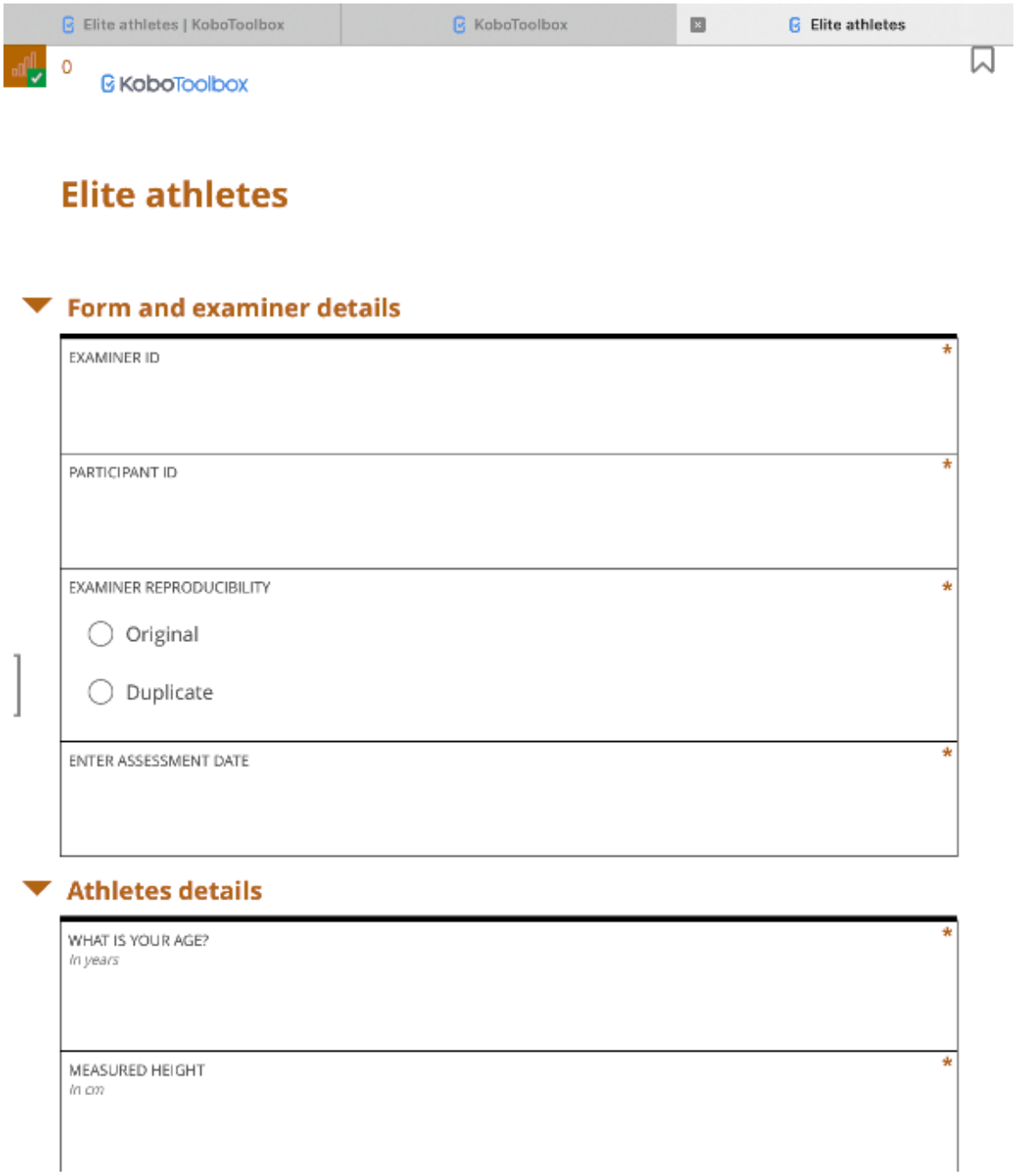


Figure 4.1 Screenshot of data collection form KoBoToolbox A, Form and examiner details, athlete details.

Note the * (red asterisk) indicates a question must be answered before being able to complete and submit the form.

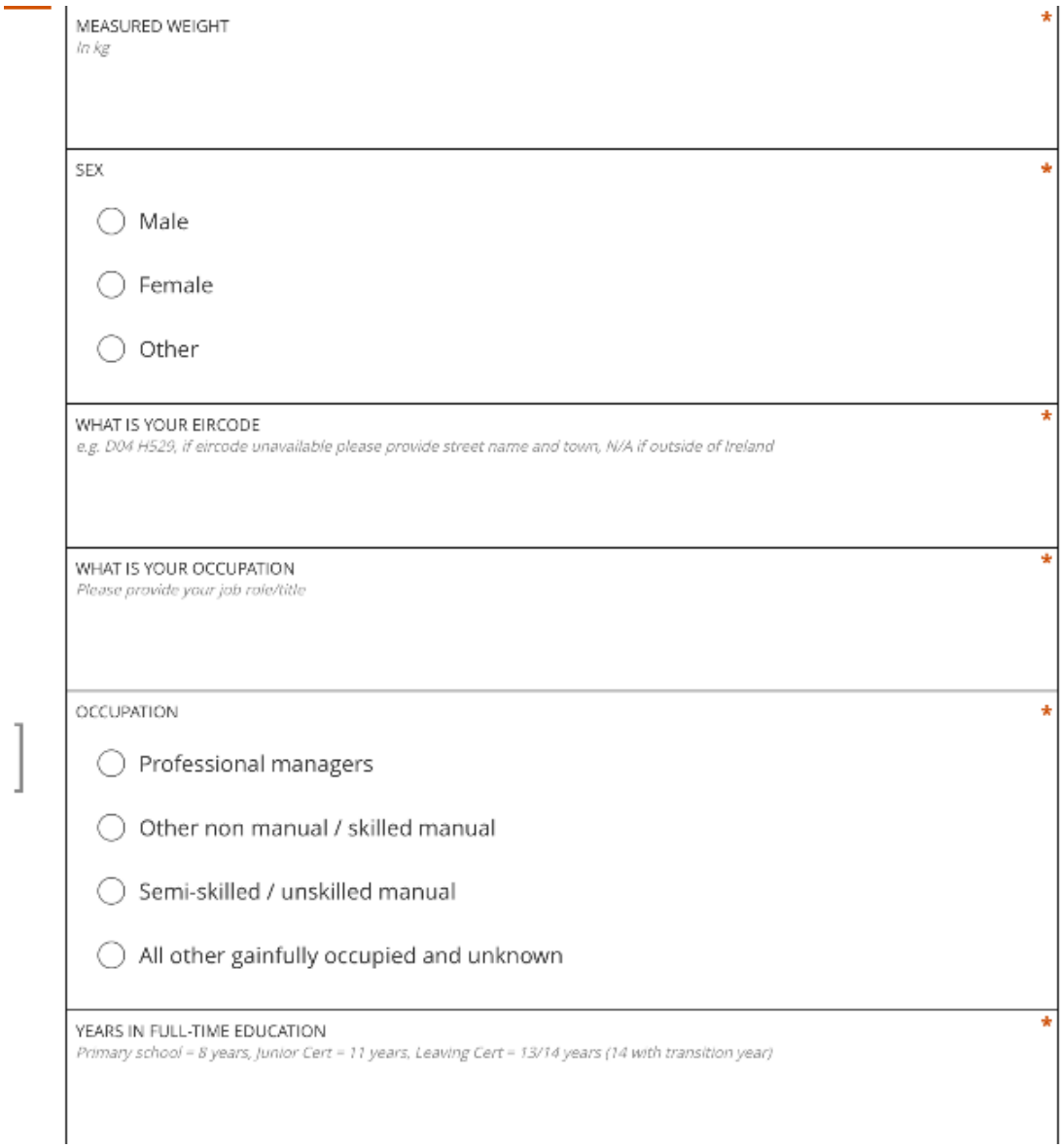


Figure 4.2 Screenshot of data collection form KoBoToolbox B, measured weight, sex, Eircode, occupation, years in full-time education.

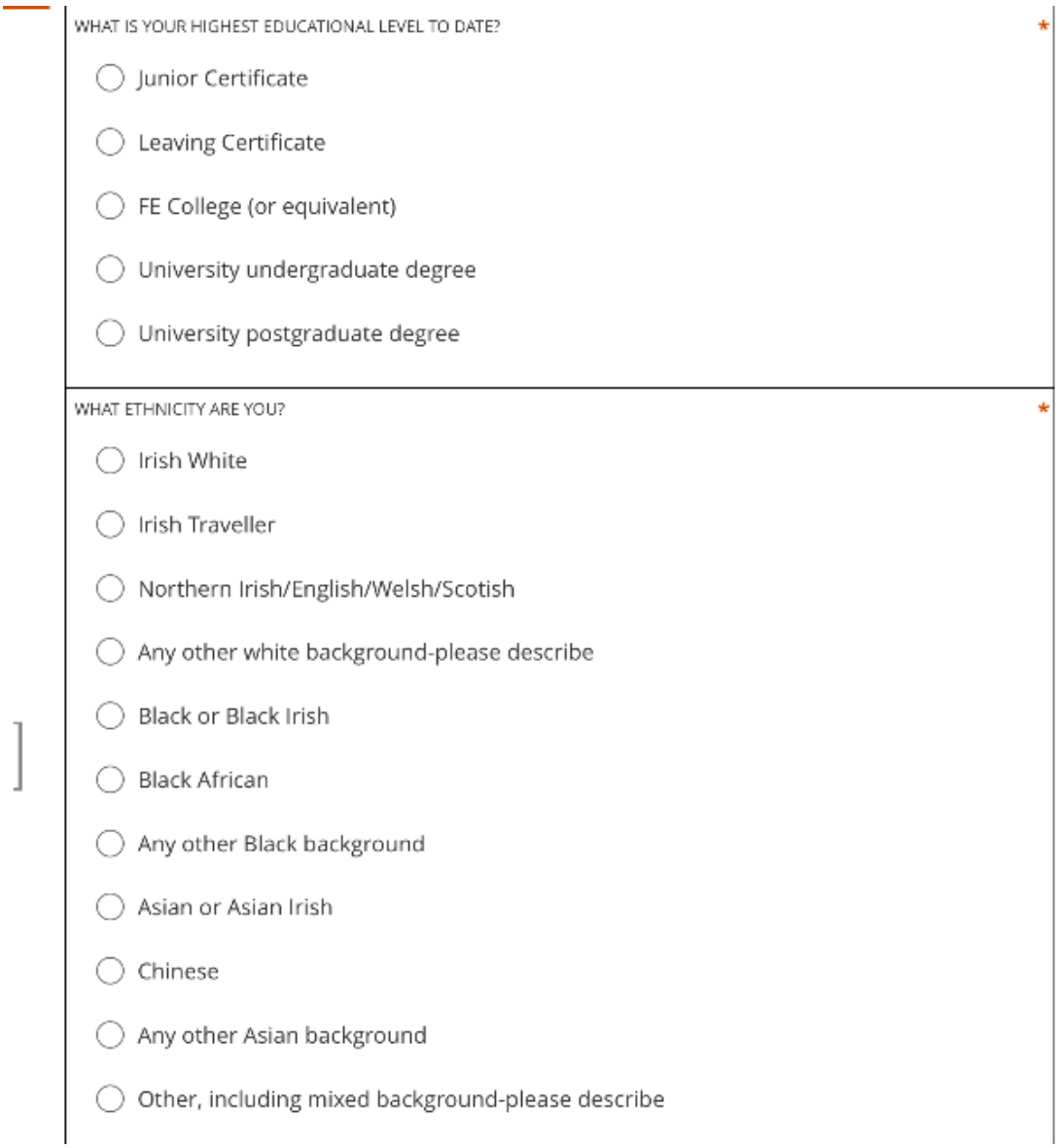


Figure 4.3 Screenshot of data collection form KoBoToolbox C, highest education level to date, ethnicity.

Dental examination (for dentist only)

ICDAS II

CORONAL ICDAS SCORE-10 = SURFACE NOT RESTORED OR SEALED1 = SEALANT, PARTIAL2 = SEALANT, FULL3 = TOOTH COLORED RESTORATION4 = AMALGAM RESTORATIONS = STAINLESS STEEL CROWN6 = PORCELAIN OR GOLD OR PFM CROWN OR VENEER7 = LOST OR BROKEN RESTORATION8 = TEMPORARY RESTORATION96= TOOTH SURFACE CANNOT BE EXAMINED97: TOOTH MISSING BECAUSE OF CARIES98: TOOTH MISSING FOR REASONS OTHER THAN CARIES99: UNERUPTED

CORONAL ICDAS SCORE-20 = SOUND1 = FIRST VISUAL CHANGE IN ENAMEL2 = DISTINCT VISUAL CHANGE IN ENAMEL3 = LOCALISED ENAMEL BREAKDOWN (WITHOUT CLINICAL VISUAL SIGNS OF DENTINAL INVOLVEMENT)4 = UNDERLYING DARK SHADOW FROM DENTINE5 = DISTINCT CAVITY WITH VISIBLE DENTINE6 = EXTENSIVE DISTINCT CAVITY WITH VISIBLE DENTINE

DENTITION STATUS UPPER RIGHT	18	17	16	15	14	13	12	11
SCORE-1	* 0	* 0	* 0	* 0	* 0	* 0	* 0	* 0
SCORE-2	* 0	* 0	* 0	* 0	* 0	* 0	* 0	* 0
DENTITION STATUS UPPER LEFT	21	22	23	24	25	26	27	28
SCORE-1	* 0	* 0	* 0	* 0	* 0	* 0	* 0	* 0
SCORE-2	* 0	* 0	* 0	* 0	* 0	* 0	* 0	* 0

Figure 4.4 Screenshot of data collection form KoBoToolbox, ICDAS II Maxillary arch.

DENTITION STATUS LOWER LEFT	38	37	36	35	34	33	32	31
SCORE-1	* 0	* 0	* 0	* 0	* 0	* 0	* 0	* 0
SCORE-2	* 0	* 0	* 0	* 0	* 0	* 0	* 0	* 0
DENTITION STATUS LOWER RIGHT	41	42	43	44	45	46	47	48
SCORE-1	* 0	* 0	* 0	* 0	* 0	* 0	* 0	* 0
SCORE-2	* 0	* 0	* 0	* 0	* 0	* 0	* 0	* 0

BEWE

BASIC EROSIVE WEAR EXAMINATION (BEWE)	17-14	13-23	24-27
SCORE-1	* ...	* ...	* ...
SCORE-2	* ...	* ...	* ...
BASIC EROSIVE WEAR EXAMINATION (BEWE)	47-44	43-33	34-37

Figure 4.5 Screenshot of data collection form KoBoToolbox E, ICDAS II mandibular arch, BEWE.

BPE

BASIC PERIODONTAL EXAMINATION	17-14	13-23	24-27
SCORE-1	* ...	* ...	* ...
SCORE-2	* ...	* ...	* ...
BASIC PERIODONTAL EXAMINATION	47-44	43-33	34-37

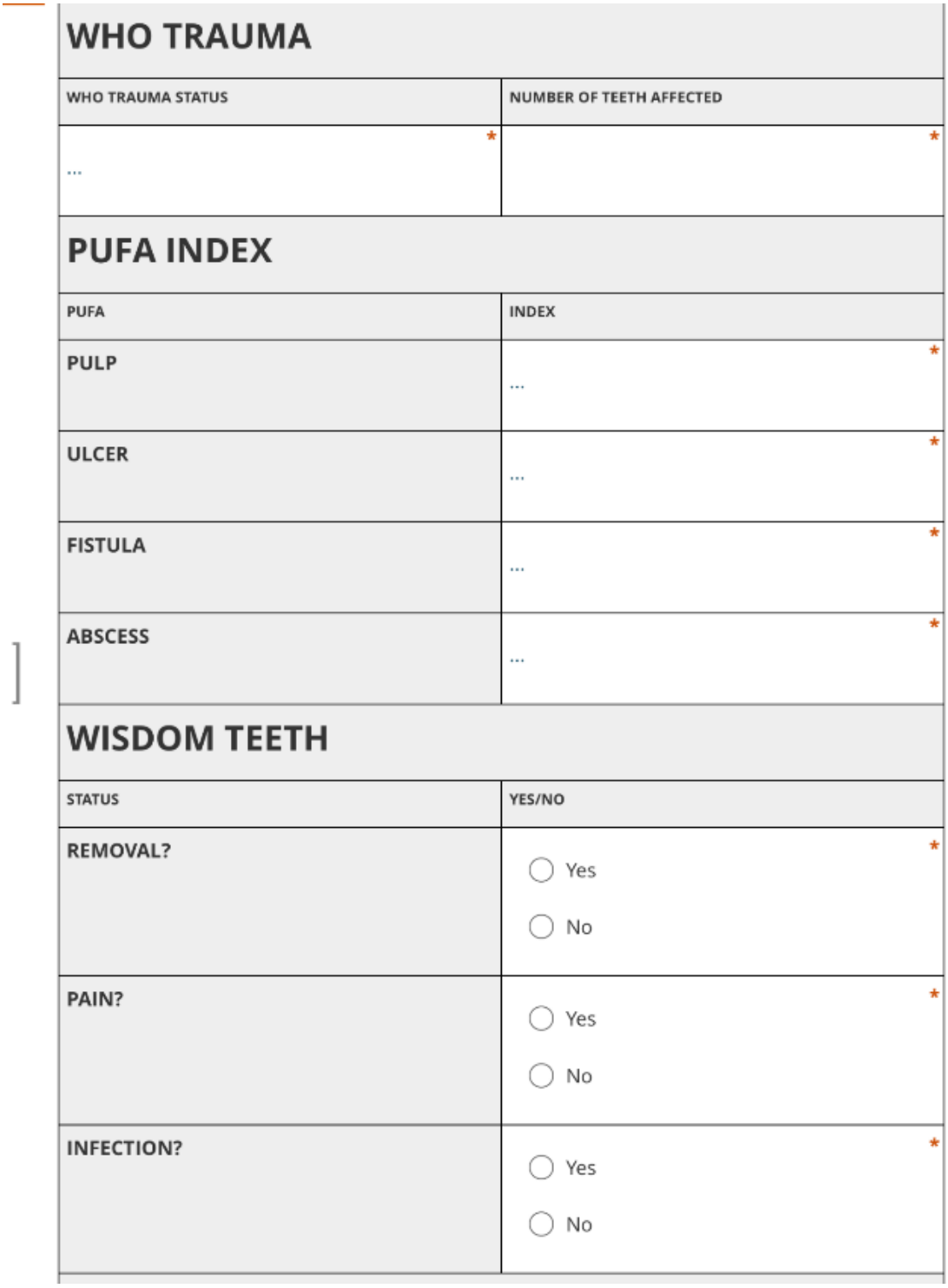
WHO TRAUMA

WHO TRAUMA STATUS	NUMBER OF TEETH AFFECTED
* ...	*

PUFA INDEX

PUFA	INDEX
PULP	* ...
ULCER	* ...

Figure 4.6 Screenshot data collection form KoBoToolbox F, BPE, WHO trauma, PUFA.



WHO TRAUMA

WHO TRAUMA STATUS	NUMBER OF TEETH AFFECTED
* ...	*

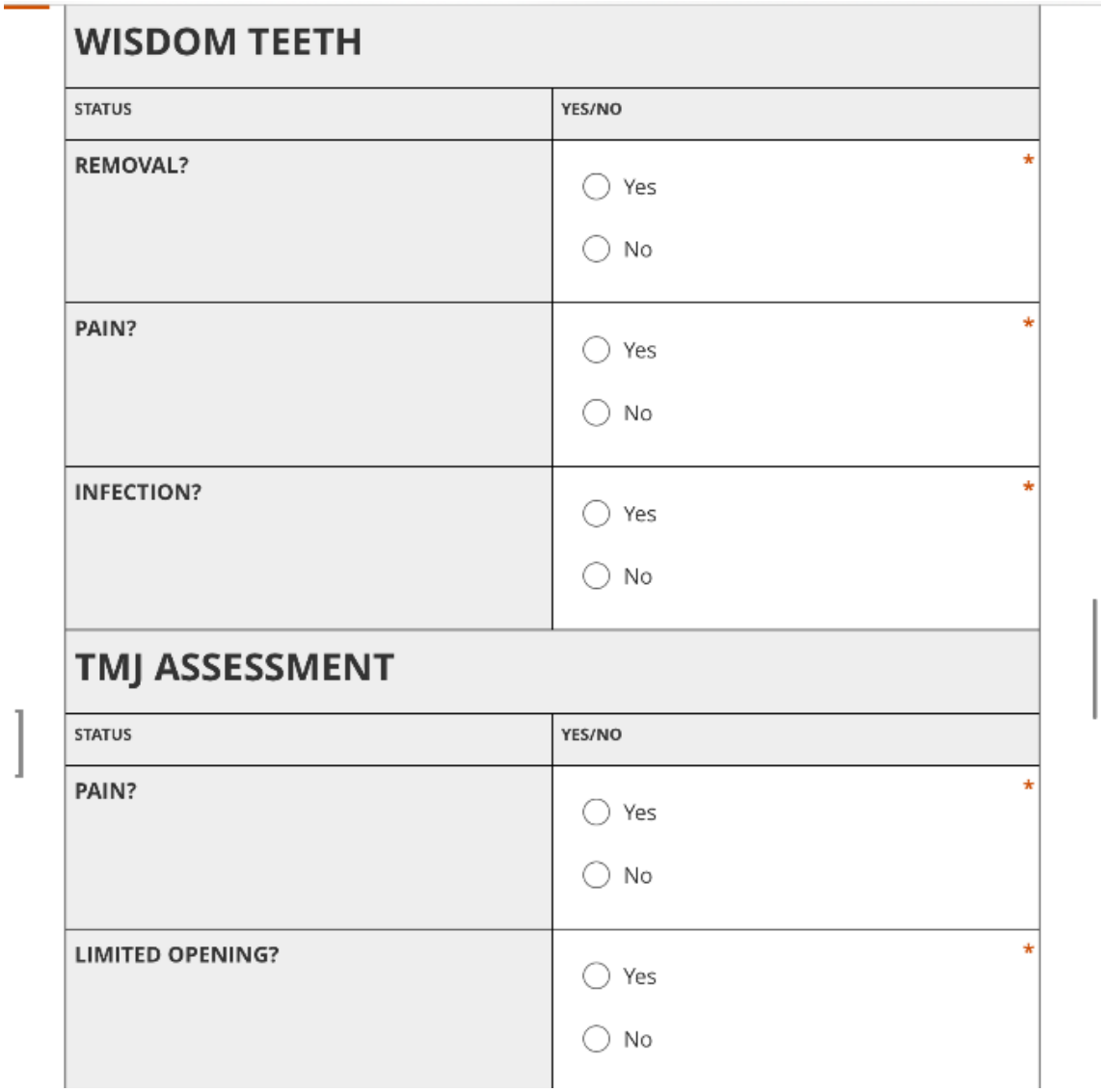
PUFA INDEX

PUFA	INDEX
PULP	* ...
ULCER	* ...
FISTULA	* ...
ABSCESS	* ...

WISDOM TEETH

STATUS	YES/NO
REMOVAL?	* ○ Yes ○ No
PAIN?	* ○ Yes ○ No
INFECTION?	* ○ Yes ○ No

Figure 4.7 Screenshot of data collection form KoBoToolbox G, WHO trauma, PUFA, and Wisdom teeth status.



WISDOM TEETH

STATUS	YES/NO
REMOVAL?	* ◯ Yes ◯ No
PAIN?	* ◯ Yes ◯ No
INFECTION?	* ◯ Yes ◯ No

TMJ ASSESSMENT

STATUS	YES/NO
PAIN?	* ◯ Yes ◯ No
LIMITED OPENING?	* ◯ Yes ◯ No

Figure 4.8 Screenshot of data collection form KoBoToolbox H, Wisdom teeth status, TMJ assessment.

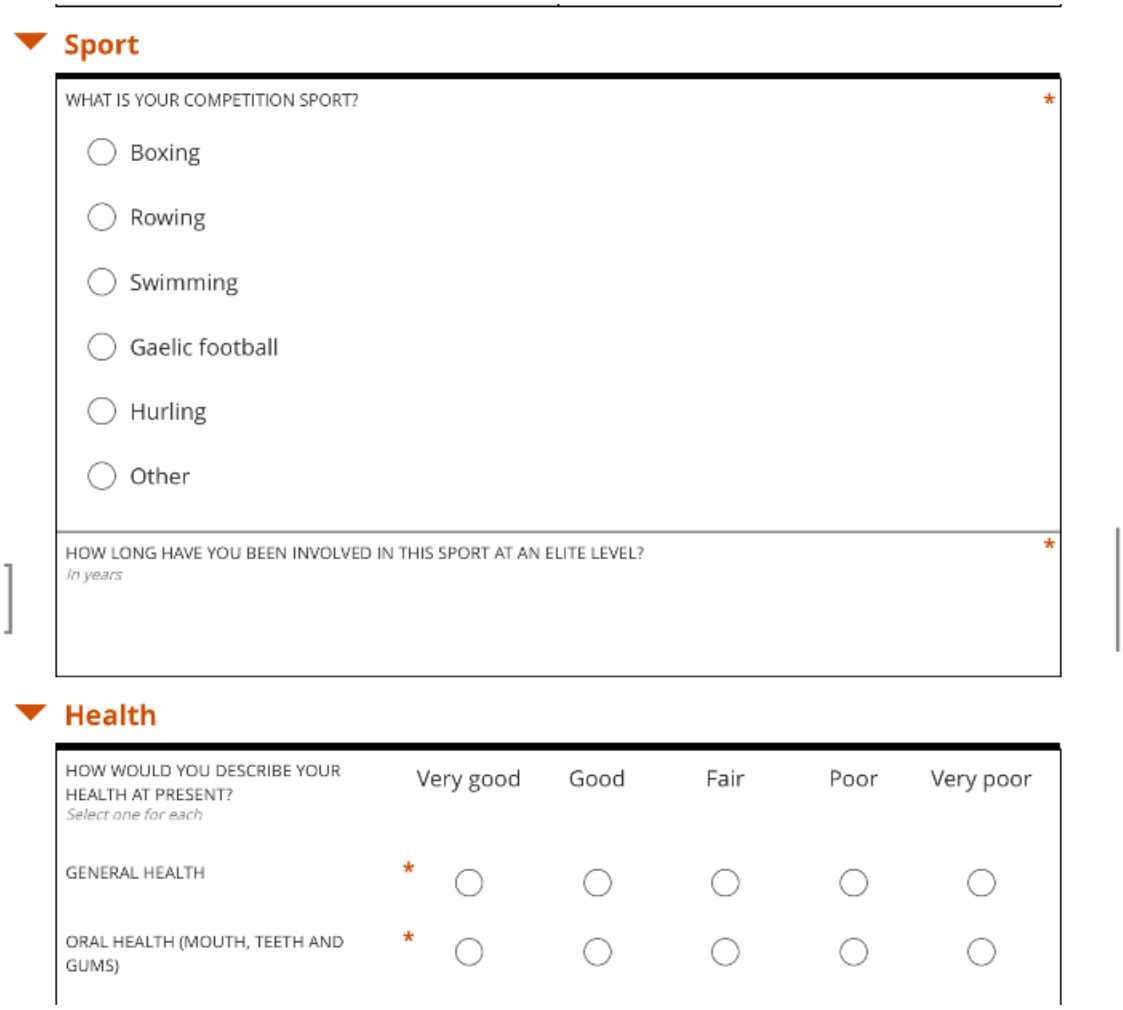


Figure 4.9 Screenshot of data collection form KoBoToolbox I, Sport, Time at elite level, and Health perceptions.

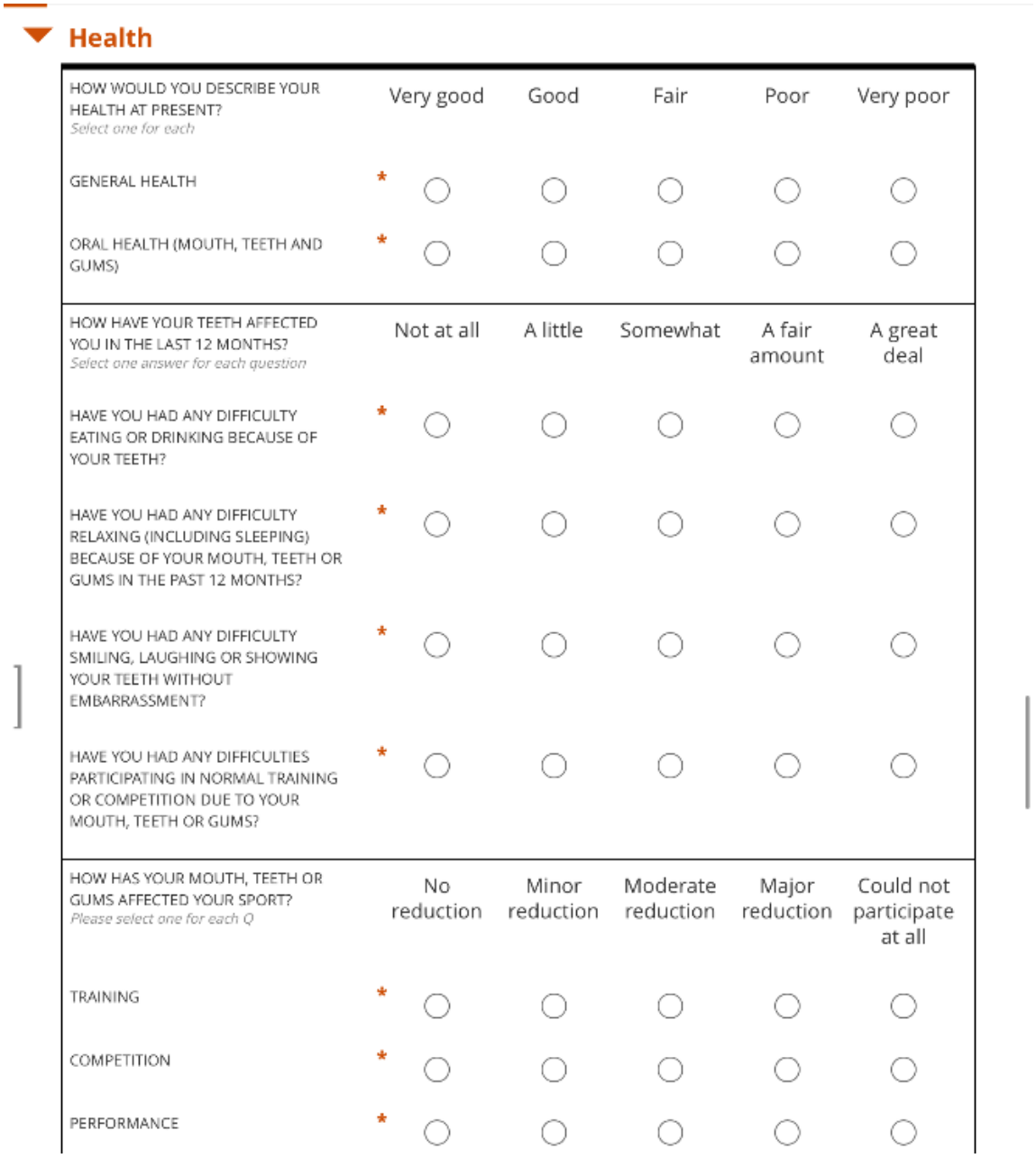


Figure 4.10 Screenshot of data collection form KoBoToolbox J, Health perception, Oral health impact on daily life, Oral health impact on training, competition and performance.

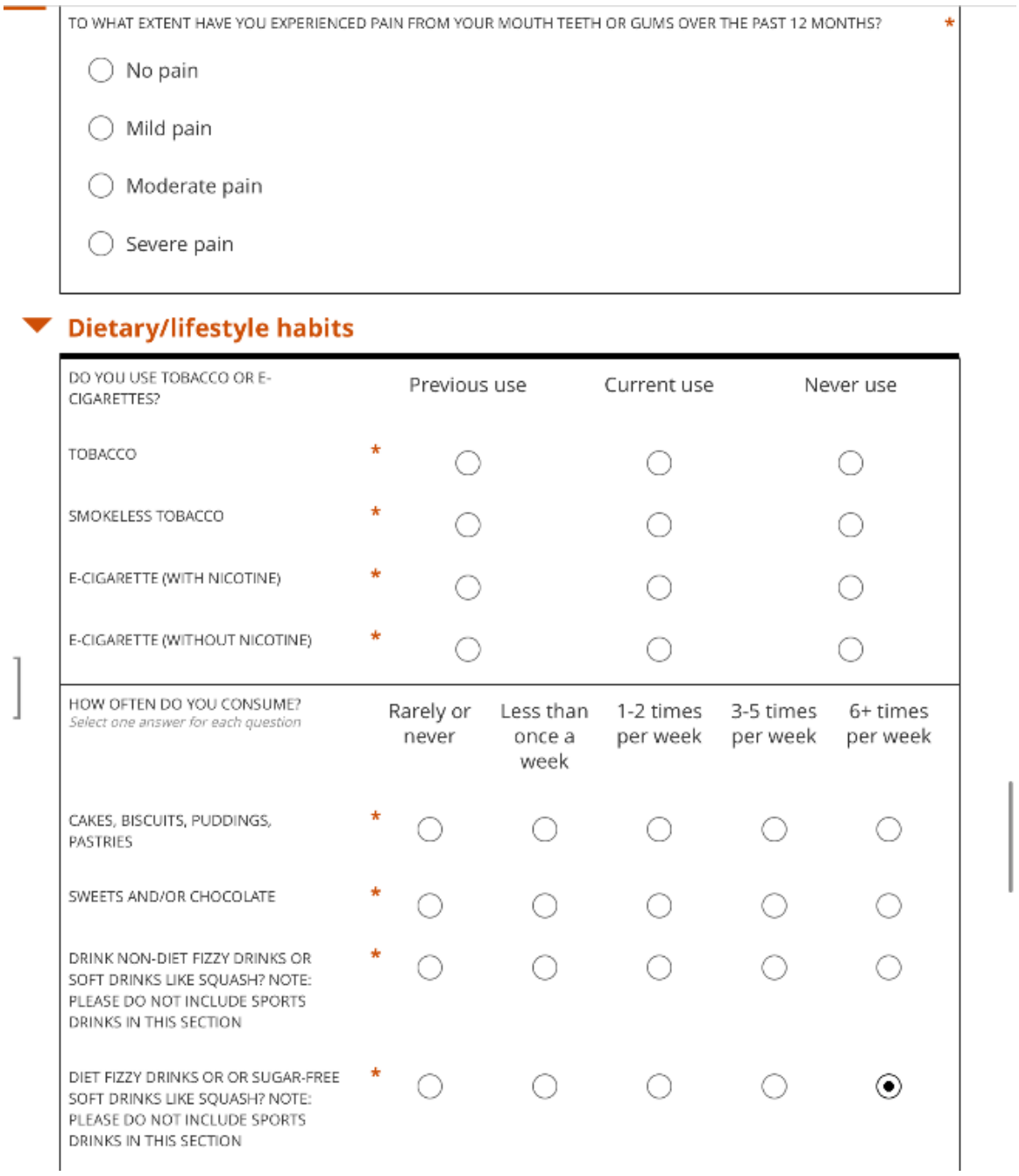


Figure 4.11 Screenshot of data collection form KoBoToolbox K, Extent of pain in last 12 months, Smoking (habits) status, Consumption of specified food and beverages.

Figure 4.12 Screenshot of data collection form KoBoToolbox L, Energy bar consumption, Energy bar brand, Energy gel consumption, and Energy gel brand.

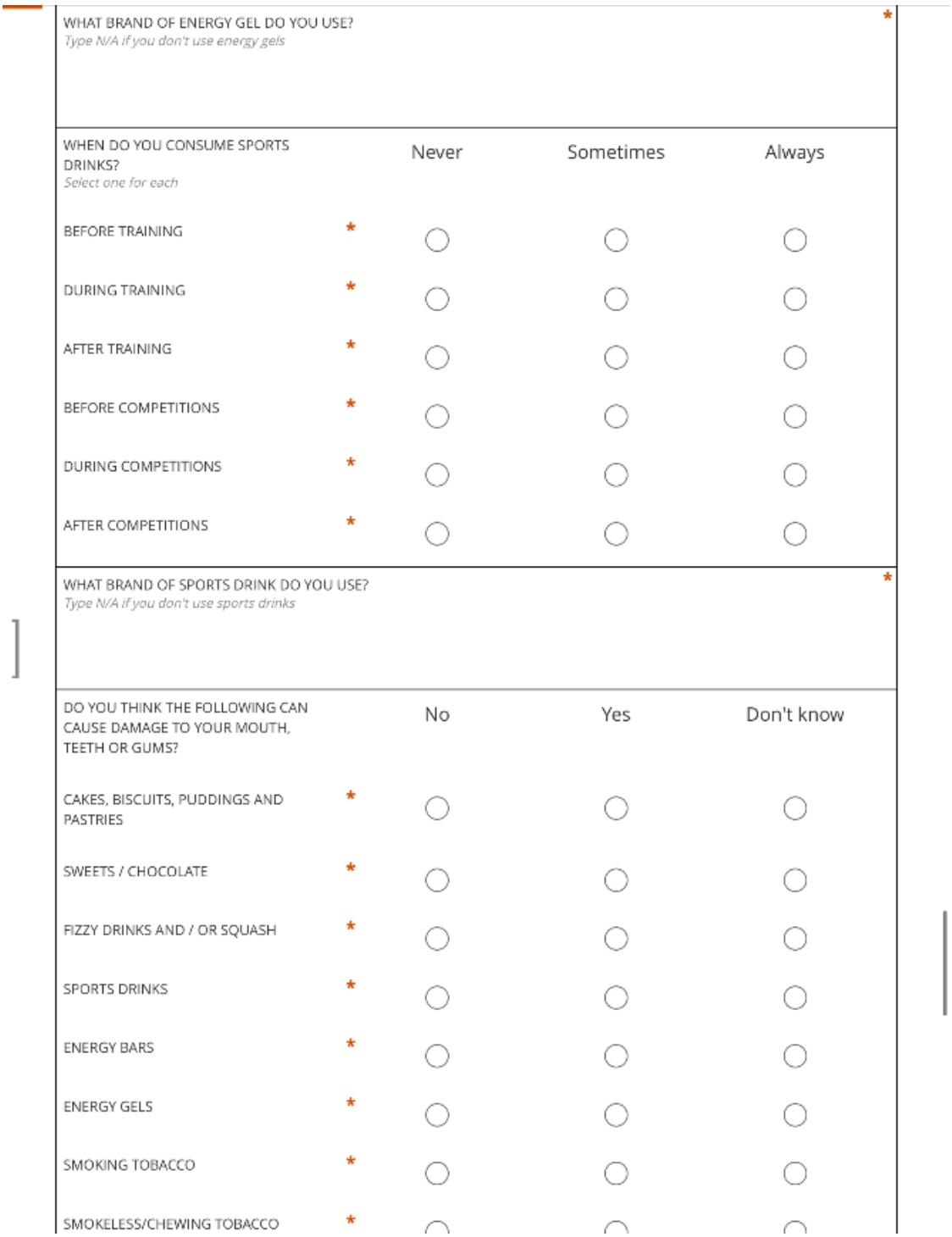
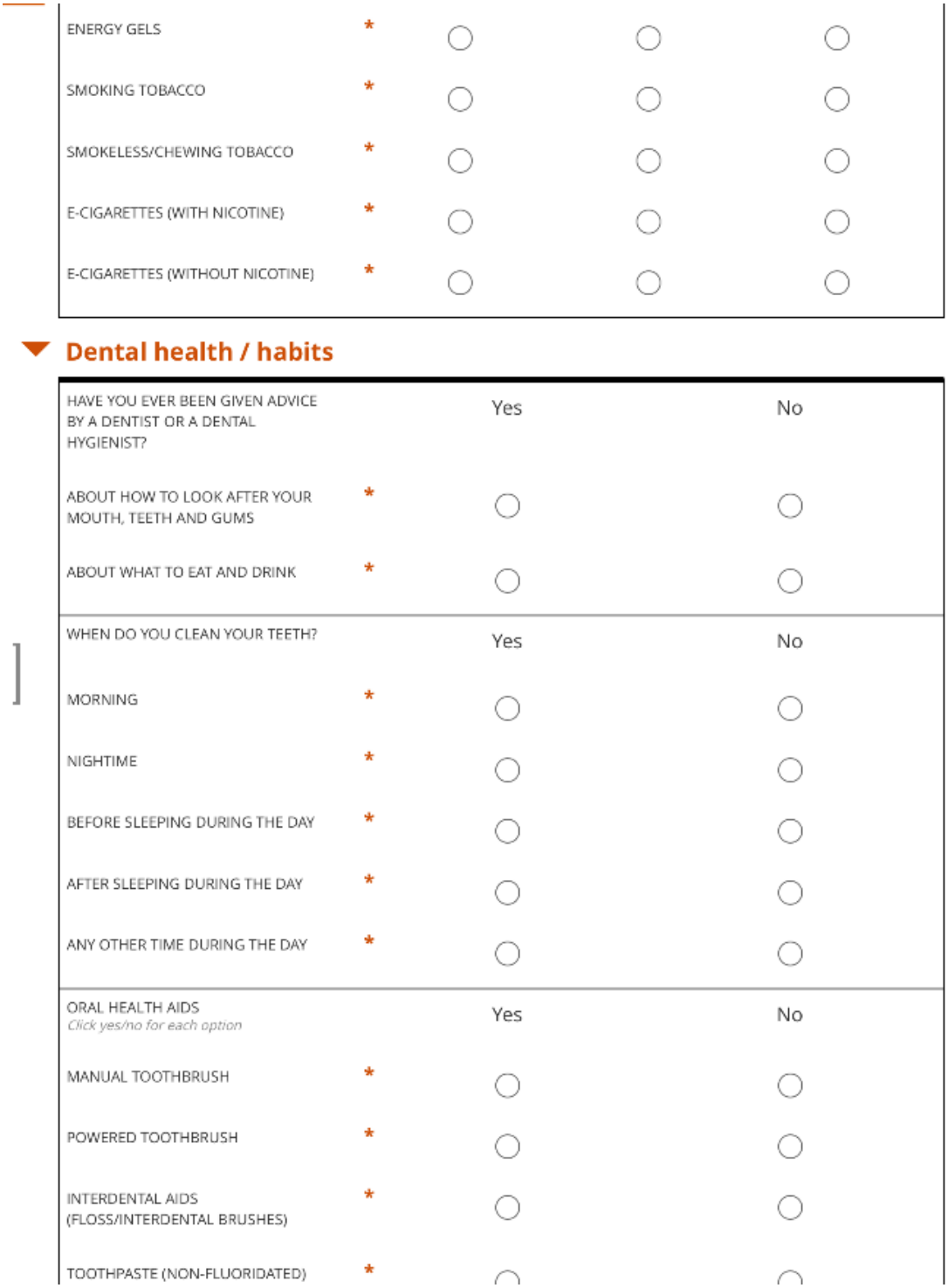


Figure 4.13 Screenshot of data collection form KoBoToolbox M, Sports drink consumption, Sports drink brand, and Behaviour perception.



ENERGY GELS	*	○	○	○
SMOKING TOBACCO	*	○	○	○
SMOKELESS/CHEWING TOBACCO	*	○	○	○
E-CIGARETTES (WITH NICOTINE)	*	○	○	○
E-CIGARETTES (WITHOUT NICOTINE)	*	○	○	○

Dental health / habits

HAVE YOU EVER BEEN GIVEN ADVICE BY A DENTIST OR A DENTAL HYGIENIST?		Yes	No
ABOUT HOW TO LOOK AFTER YOUR MOUTH, TEETH AND GUMS	*	○	○
ABOUT WHAT TO EAT AND DRINK	*	○	○

WHEN DO YOU CLEAN YOUR TEETH?		Yes	No
MORNING	*	○	○
NIGHTIME	*	○	○
BEFORE SLEEPING DURING THE DAY	*	○	○
AFTER SLEEPING DURING THE DAY	*	○	○
ANY OTHER TIME DURING THE DAY	*	○	○

ORAL HEALTH AIDS *Click yes/no for each option*		Yes	No
MANUAL TOOTHBRUSH	*	○	○
POWERED TOOTHBRUSH	*	○	○
INTERDENTAL AIDS (FLOSS/INTERDENTAL BRUSHES)	*	○	○
TOOTHPASTE (NON-FLUORIDATED)	*	○	○

Figure 4.14 Screenshot of data collection form KoBoToolbox N, Professional dietary advice, Professional oral hygiene instruction, and Use of oral health aids.

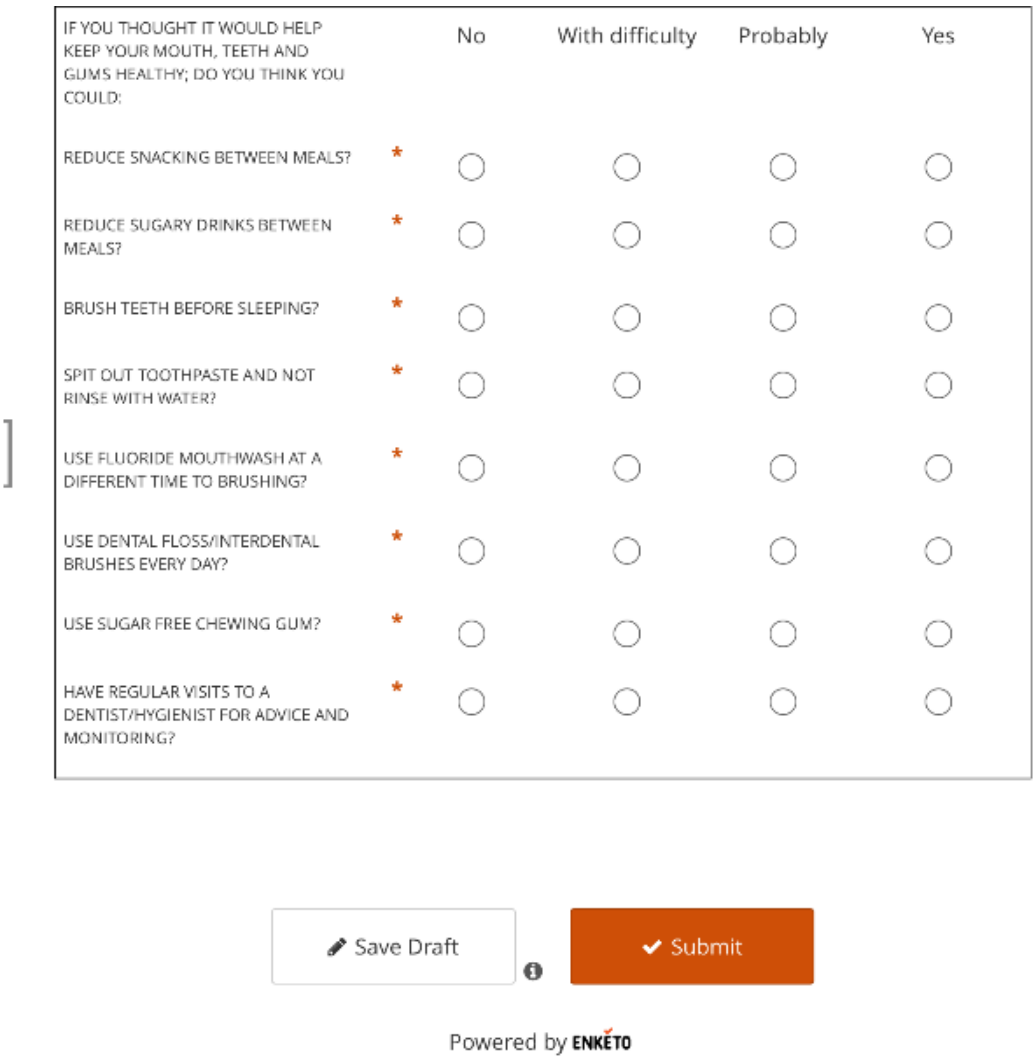
ORAL HEALTH AIDS *Click yes/no for each option*		Yes	No
MANUAL TOOTHBRUSH	*	◯	◯
POWERED TOOTHBRUSH	*	◯	◯
INTERDENTAL AIDS (FLOSS/INTERDENTAL BRUSHES)	*	◯	◯
TOOTHPASTE (NON-FLUORIDATED) E.G. EUTHYMOL	*	◯	◯
TOOTHPASTE (FLUORIDATED)	*	◯	◯
MOUTHWASH	*	◯	◯
SUGAR-FREE CHEWING GUM	*	◯	◯
GUM SHIELD	*	◯	◯

HOW LONG AGO WAS YOUR LAST VISIT TO THE DENTIST? *

- ◯ Within the past 6 months
- ◯ 6-12 months ago
- ◯ 1-2 years ago
- ◯ More than 2 years ago

IF YOU THOUGHT IT WOULD HELP KEEP YOUR MOUTH, TEETH AND GUMS HEALTHY; DO YOU THINK YOU COULD:		No	With difficulty	Probably	Yes
REDUCE SNACKING BETWEEN MEALS?	*	◯	◯	◯	◯
REDUCE SUGARY DRINKS BETWEEN MEALS?	*	◯	◯	◯	◯
BRUSH TEETH BEFORE SLEEPING?	*	◯	◯	◯	◯
SPIT OUT TOOTHPASTE AND NOT RINSE WITH WATER?	*	◯	◯	◯	◯
USE FLUORIDE MOUTHWASH AT A	*	◯	◯	◯	◯

Figure 4.15 Screenshot of data collection form KoBoToolbox O, Use of oral health aids, Last visit to dentist, and Behaviour modifications.



IF YOU THOUGHT IT WOULD HELP KEEP YOUR MOUTH, TEETH AND GUMS HEALTHY; DO YOU THINK YOU COULD:		No	With difficulty	Probably	Yes
REDUCE SNACKING BETWEEN MEALS?	*	○	○	○	○
REDUCE SUGARY DRINKS BETWEEN MEALS?	*	○	○	○	○
BRUSH TEETH BEFORE SLEEPING?	*	○	○	○	○
SPIT OUT TOOTHPASTE AND NOT RINSE WITH WATER?	*	○	○	○	○
USE FLUORIDE MOUTHWASH AT A DIFFERENT TIME TO BRUSHING?	*	○	○	○	○
USE DENTAL FLOSS/INTERDENTAL BRUSHES EVERY DAY?	*	○	○	○	○
USE SUGAR FREE CHEWING GUM?	*	○	○	○	○
HAVE REGULAR VISITS TO A DENTIST/HYGIENIST FOR ADVICE AND MONITORING?	*	○	○	○	○

Figure 4.16 Screenshot of data collection form KoBoToolbox P, Behaviour modification, Form submission.

Note the * (red asterisk) indicating that the question must be answered before being able to complete and submit the form.