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REVIEW ARTICLE

Is international junior success a reliable predictor for international senior success in elite combat sports?

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Abstract
Currently in the literature, there is a dearth of empirical research that confirms whether international junior success is a reliable predictor for future international senior success. Despite the uncertainty of the junior–senior relationship, federations and coaches still tend to use junior success as a predictor for long-term senior success. A range of former investigations utilising a retrospective lens has merely focused on success that athletes attained at junior level competitions. Success that was achieved at senior-level competitions but at a junior age was relatively ignored. This study explored to what extent international senior success can be predicted based on success that athletes achieved in either international junior level competitions (i.e. *junior medalists*) or senior competitions at a junior age (i.e. early *achievers*). The sample contains 4011 international male and female athletes from three combat sports (taekwondo, wrestling and boxing), who were born between 1974 and 1990 and participated in both international junior and senior-level competitions between 1990 and 2016. Gender and sport differences were compared. The results revealed that 61.4% of the *junior medalists* and 90.4% of the *early achievers* went on to win international medals at a senior age. Among the *early achievers*, 92.2% of the taekwondo athletes, 68.4% of the wrestling athletes and 37.9% of the boxing athletes could be reliably "predicted" to win international senior medals. The findings demonstrate that specific to the three combat sports examined, international junior success appears to be an important predictor to long-term international senior success.

Keywords: *Combat sports, talent development, predicting success, elite performance, discriminant analysis*

Highlights
- Driven by the global sporting arms race, understanding the junior-senior relationship and the possibility of using junior success to predict senior success insists NGBs in making talent development programs.
- A range of studies has focused on success that athletes achieved at junior level competitions; success that was achieved at senior level competitions at a junior age was relatively ignored.
- Different role that junior success has been playing at different stage of talent identification and development.

Introduction

Over the last three decades, there has been an increasing awareness of the value of elite sporting success, whereby governments across the global landscape invest substantial sums of public money in elite sport in order to improve or maintain their success at the international level (De Bosscher, Shibli, Westerbeek, & van Bottenburg, 2015). Driven by this global sporting arms race, national governing bodies are facing an increasing pressure to deliver collective success and implementing elite athlete development programmes that optimise athlete recruitment, retention and advancement at an increasingly younger age (Cooke, Cobley, Till, & Wattie, 2010, Green, 2005). However, predicting and manufacturing outcomes are incredibly challenging, as athletic development is a complex interplay of athlete, environmental, system and chance factors that have varying degrees of influence on athletic development (Weissensteiner et al., 2017). Various researchers

have tried to identify the indicators that can help to predict eventual senior success based on technical (Sadowski, Gierczuk, Miller, & Cieśliński, 2012), physical (García-Pallarés, López-Gullón, Muriel, Díaz, & Izquierdo, 2011) physiological, biomechanical, psychological and sociological factors (e.g. Abbott & Collins, 2004; Mohamed et al., 2009). Few studies have looked at junior success as an indicator to predict international competitive success at a senior level.

Recently, there has been an increasing interest in uncovering the relationship between junior success and senior success. In the literature (see Appendix 1 for an overview), some studies (e.g. Brouwers, De Bosscher, & Sotiriadou, 2012; Güllich & Emrich, 2014; Similarly, Barreiros, Côté, & Fonseca, 2014) demonstrated a low correlation and even a seemingly negative correlation between junior success and senior success, while other studies (Hollings, 2006; Scholz, 2006) argued that success in junior competition is becoming an increasingly important prerequisite for later success. Several methodological gaps are apparent within these studies. Firstly, the results are inconsistent regarding whether international junior success is a reliable predictor for international senior success. Secondly, the majority of these studies have focused on success that athletes achieved at junior level competitions; success that was achieved at senior-level competitions at a junior age was relatively ignored. Thirdly, potential differences between genders are not commonly considered. It is readily acknowledged that the maturational time course of male and female athletes is quite different (Meylan, Cronin, Oliver, & Hughes, 2010), it is therefore necessary to be gender-specific when examining their developmental and competitive journeys. Furthermore, according to Pion (2015), the processes of talent identification and development (TID) system is divided into different stages, i.e. orientation, talent detection/identification, development and confirmation stages. Among the aforementioned investigations (Brouwers et al., 2012; Güllich & Emrich, 2014; Similarly, Barreiros et al., 2014) that revealed a low correlation between junior and senior competitive success, many focused athletes that were at the very early phase of TID and were consequently quite young and competing at lower levels of competitions (e.g. regional or national). Athletes who were at a later developmental phase (i.e. confirmed talents) competing at higher levels of competition (e.g. international) were rarely examined (Sadowski et al., 2012). Lastly, to our knowledge, the prediction of later senior competitive success by incorporating junior success has not yet been addressed in combat sports. Despite these apparent theoretical gaps, in practice, sporting stakeholders including sporting federations and their coaches still rely on junior competitive result as an indicator of later senior competitive success, particularly in relation to selecting and funding sporting talent. In order to extend the current knowledge, this study sought to explore to what extent international junior-aged success at different levels (i.e. junior and/or senior competition level) can be used to predict winning later international senior medals in the combat sports of taekwondo, boxing and wrestling.

The outcomes and contributions of this research are twofold. Theoretically, this study contributes to the literature regarding talent development by illustrating the role that junior success at two different levels (junior/senior) in predicting winning international senior medals specific to combat sports. Secondly, by examining athletes who are at a higher level of international competition, this paper fills the literature gap regarding the role of junior success in predicting senior success at a later phase of talent development system. Practically, policymakers, high-performance managers and coaches will be informed more objectively concerning the relative contribution of junior success in the development of senior success, thus inform appropriate talent support and commensurate coach education and delivery.

Method

Data

Data were extracted from Gracenote, which is the world leading technology company that captures and delivers in-depth sports performance data. International junior and senior competition results in the three combat sports (i.e. taekwondo, wrestling and boxing) were retreated, including European Junior Championships, World Junior Championships, Olympic Games, World Championships and Continental championships between 1990 and 2016. Athletes' names, date of birth, competing age, gender, performance results (rankings and medals) were exported into an Excel database. To ensure inclusion of both an athlete's junior and senior competition results within the observational time period (1990–2016), only athletes who were born between 1974 and 1990 were selected, resulting in a total sample of 4011 athletes.

Categorisation of competitive pathways

Excellence in sport has been conceptualised in terms of outcomes (competition results) and measured in the form of medals, records and victories (Penney, 2000). In this research, junior success is thus measured by athletes' best competitive results
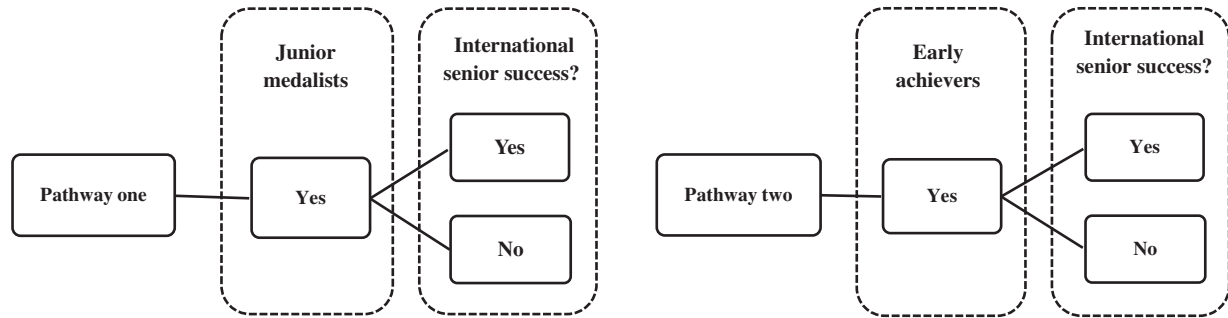
Figure 1. The "transition map" from international junior to senior success across the two defined competitive pathways. Note: Junior medalists: Athletes won medals at international junior competitions Early achievers: Athletes won medals at international senior competitions at junior age International senior success: athletes won international medals at a senior age.

(i.e. medals). To explore the role of junior success at two different levels of competition (i.e. junior: under-age and senior: open age) in predicting future senior international medals, two primary competitive pathways that a junior athlete could achieve are visualised in Figure 1. Accordingly, the sample was divided into two groups based on their competitive pathways, as

Pathway one: 1913 athletes (taekwondo, $n = 774$; wrestling, $n = 980$; boxing, $n = 159$) who competed at an international junior level of competition and later progressed to international senior-level competitions at a senior age (e.g. age >18 years) were analysed. Athletes, who won a junior international medal through this trajectory, are here-on referred to as "junior medalists" within this paper.

Pathway two: 2098 athletes (taekwondo, $n = 1119$; wrestling, $n = 795$; boxing, $n = 184$) who competed at an international senior-level of competition whilst at a junior (i.e. under 18) age as well as at a senior age, were analysed. Athletes that won a senior international medal whilst at a junior age are here-on referred to as "early achievers" within this paper.

To examine the extent to which athletes can maintain their success from international junior level to international senior level, a descriptive analysis was applied to calculate the number of *junior medalists* and *early achievers* that went on to win medals at a senior age. Secondly, discriminant analysis (DA) was used to explore to what extent junior success (competition results) could distinguish medalists from non-medalists in senior international level competition. DA provides a useful way to build a predictive model of group membership based on several variables (Anderson & Robinson, 2003). More recently, this technique has been utilised in sport research. For example, Sgrò, Barresi, Lipoma (2015) applied DA to identify indicators related to team match performances that could effectively predict winning or losing teams in a Football Championship. Similarly in basketball, DA has been heavily utilised to predict NBA

playoff results (Ergül, Yavuz, & Yavuz, 2014). Specific to this study, regarding the usage of DA, the independent variable was "junior success" measured by the competition results which were represented by six sub-variables (i.e. total number of gold/silver/bronze medals won, colour of medals won, whether or not won medals and total number of medals won). An illustration of how the independent variables, grouping variables and the coding of these variables were utilised within the DA is provided in Appendix 2.

Additionally, a Mann–Whitney U test was used to identify and confirm any differences between the genders and between the two competitive pathways. A Kruskal–Wallis test was conducted to test differences across the three combat sports.

All statistical analyses were performed initially with Excel software and its customised tools (e.g. PivotTables and VLOOKUP) followed by further analyses utilising SPSS software (Version 24). Results were considered statistically significant when $p < .05$.

Results

In this section, results specific to the two competitive pathways are detailed descriptively, followed by results specific to potential gender and sport-specific differences. The following section focuses on statistical findings specific to the predictive power of winning international senior medals

Maintaining international success from a junior age to senior age in the two competitive pathways

Table I shows the percentages of successful junior athletes who made it to a senior international competitive level within the two competitive pathways across the three combat sports. In pathway one, the results showed that a total of 61.4% of the *junior medalists* succeeded in winning medals at senior

Table I. The percentage of athletes that maintained their international competitive success from a junior to senior age across the two competitive pathways.

	Male		Female		
	Junior success (*n*)	Senior success *n* (%)	Junior success (*n*)	Senior success *n* (%)	Total (F + M) (%)
Pathway one					
Taekwondo	72	30 (41.6)	98	52 (53.1)	47.4
Wrestling	126	76 (60.3)	185	121 (65.4)	62.9
Boxing	59	49 (83.1)	10	10 (100.0)	91.5
Total	257	155 (60.3)	293	183 (62.5)	61.4
Pathway two					
Taekwondo	483	473 (97.9)	522	497 (95.2)	96.6
Wrestling	152	125 (82.2)	229	183 (79.9)	81.0
Boxing	63	34 (54.0)	13	9 (69.2)	61.6
Total	698	632 (90.5)	764	689 (90.2)	90.4

international level competitions, with 47.4%, 62.9% and 91.5% of athletes from taekwondo, wrestling and boxing respectively. A follow-up Kruskal–Wallis test revealed significant differences across the three sports (H (2) = 6.61, p = .037). Specific to the gender comparison, there were significantly more female than male athletes who went on to win senior international level medals in taekwondo (U = 70455, z = −.38, p = .008) and wrestling (U = 107,552, z = −2.2, p = .000). Interestingly, there was no gender difference apparent in boxing (U = 7275, z = −.66, p = .13).

In pathway two, the results revealed that a total of 90.4% of the *early achievers* (taekwondo 96.6%, wrestling 81.0% and boxing 61.6%) went on to win senior international medals. A follow-up Kruskal–Wallis test confirmed significant differences across the three combat sports (H (2) = 201.63, p = 0.000). Specific to the gender comparison, there were significantly more male than female athletes who went on to win senior international medals in taekwondo (U = 500,070, z = −5.8, p = .000) with no gender differences apparent in wrestling (U = 72547, z = −1.8, p = .34) and boxing (U = 2817, z = −1.6, p = .961).

Predicting winning international senior medals based on junior competitive performance

A DA was conducted to examine whether "junior success" could distinguish senior international medalists from non-medalists. The DA was statistically significant (p < .05) when canonical discriminant functions were examined. Specific to athletes characterised by development pathway one, the canonical correlation (R) and effect size (R^2) were low (taekwondo, R = .21, R^2 = 4.2%; wrestling, R = .25, R^2 = 6.2%), suggesting that only a small variation of the outcome is accounted for by the predictors (Field, 2005). The low eigenvalues and small effect sizes indicate that the functions used in this analysis (development pathway one) did not clearly discriminate between medalists and non-medalists at a senior international level. However, for athletes characterised by development pathway two, the model of the discriminant function was found to be moderate to strong in its effect (wrestling R = 0.48, R^2 = 22.75%; taekwondo R = .89, R^2 = 79.39%). This result indicates that junior success in senior international competition accounted for 22.75% of the variance in winning senior medals in wrestling and 79.39% for taekwondo. No significant discriminant function was found for boxing (p > .05).

Table II shows the summary classification results within the three combat sports specific to competitive pathway two. It indicates the extent to which the combination of all the independent variables could predict athletes winning senior international medals. The results revealed that 92.2% of the taekwondo athletes, 68.4% of the wrestling athletes and 37.9% of the boxing athletes could be "predicted" to win senior international medals based on their success achieved in senior-level competitions at a junior age. For each sport, a slightly higher percentage of athletes who did not win medals at junior

Table II . DA classification specific to predicting future senior medals within competitive pathway two.

	No medals (%)	Won medals (%)	Correctly classified (%)
Taekwondo	96.8	92.2	94.5
Wrestling	78.8	68.4	73.0
Boxing	66.0	37.9	52.7

age were predicted not to win senior medals. Conversely, no valid predictions were found specific to competitive pathway one.

Discussion

The descriptive results revealed that 61.4% of the *junior medalists* and 90.4% of the *early achievers* went on to win senior medals at major international events. This finding indicates that "junior success" plays an important role in predicting senior international success in elite combat sports. Similar results have been reported by Reid, Crespo, Santilli, Miley, Dimmock (2007), which showed that 91% of all top 20 ranked junior tennis players from 1992 to 1998 achieved a professional men's ranking. However, a relatively low junior–senior relationship has been reported in other sports, e.g. soccer, volleyball, swimming, judo and cycling (Barreiros et al., 2014; Brito, Fonseca, & Rolim, 2004; Brouwers et al., 2012). Possible explanations for the differences with these studies may lie in their developmental focus. For instance, unlike the majority of these studies, the athlete cohort in this study had already progressed to a later phase of talent development (Pion, 2015) and consequently was at a higher competition level (e.g. international). The findings of this study can commensurate strategy and support by affirming that specific to athletes at an early developmental phase (e.g. U14) and lower competition level (e.g. regional or national), junior success is important but may not play a dominant role; it becomes more important at a higher competition level and at a later phase of talent development. Secondly, the differences may also be explained by the different methodological approaches adopted in the literature compared to that adopted in this study. Specific to the studies that claimed a low junior–senior relationship, a retrospective viewpoint was often adopted (Barreiros et al., 2014; Barreiros & Fonseca, 2012; Brito et al., 2004; Güllich & Emrich, 2014) which focused on the population of successful senior athletes that were not successful at a junior age. By contrast, this study utilised a "bottom-up" or prospective approach focusing on successful junior athletes who made it to senior international competition.

The present results also suggest that junior success achieved in senior-level competitions appeared to be a strong predictor of eventual senior success in comparison to success achieved at a junior competition level. The possible explanation underpinning this finding may lie in the required training load and high competitiveness of senior-level competition. Athletes who are able to compete and win medals

in senior competitions at a junior age, could gain valuable competitive experience; improve their physical capacity; challenge their psychological, technical and tactical aptitude within the high competitive context, which in return provides them with the critical foundations for achieving later international success at a senior level (Gulbin, Weissensteiner, Oldenziel, & Gagné, 2013). The implication of this result is that, in practice, there may well be justification to keep an athlete longer (or shorter) in a junior level of competition in order to develop long-term success. When athletes make transitions from a junior to senior level, a common characteristic of many highly talented athletes is that they have already invested in concurrent junior and senior competitive experiences at a relatively young age, and this is a critical catalyst to future competitive success (Gulbin, Croser, Morley, Weissensteiner, 2013). For some athletes, it is important to take up experiences at higher level of competitions; others are simply not ready, but can still become good athletes. Some coaches may let their athletes participate in senior competition too early or too frequently, which puts pressure on the athletes, leads to a loss of confidence and more often than not injuries and drop out. Therefore, it is critical that sport stakeholders including athletes themselves understand the potential role of concurrent junior and senior competitive success and that it must be carefully planned and managed depend on the motivation and commitment of the athlete in question as well as their technical, tactical, psychological and physical readiness for progression. The high percentage of *early achievers* that maintained their success to a senior age may serve as proof that, in combat sports, when appropriate, senior competitive exposure at a junior age when appropriate and carefully managed plays a vitally important role in the development and attainment of sporting expertise.

Meanwhile, the findings also suggest that the predictive power of junior success varies by gender and type of sport. Regarding the gender differences, the results showed that female athletes appeared to favour the junior competitive pathway in all three sports, while more male athletes maintained their junior success to a senior age through early exposure in senior-level competitions. Specific to the type of sport, the three sports showed a significant difference regarding utilising junior success to predict winning senior medals. A high predictive value was identified for taekwondo (92%) and a lower predictive value for boxing (38%). Interestingly, in boxing, success at an international junior level appeared to have a higher predictive value of eventual senior competitive success than success achieved in senior competition at a junior age (i.e. *early achievers*). In contrast,

specific to the taekwondo and wrestling athletes, experience in senior competition at a junior age is more important for eventual senior success.

Methodologically in this study, the utilisation of DA revealed an efficient way (i.e. classification of group membership) to unveil the predictive differentiation of senior international medalists from non-medalists in combat sports. This statistical technique not only provides percentages of predictive classification of group membership but also complemented the descriptive analysis. While the descriptive results revealed that 60.4% of *junior medalists* won senior medals at a junior age, the DA (through canonical correlation) further proved that the function used in competitive pathway one did not discriminate clearly between medalists and non-medalists at a senior-level of international competition. For this reason, the usefulness of DA for effective and reliable prediction of competitive outcome in sport is clearly evident.

Limitations and future study

The present study mainly focused on athletes that had been successful at a junior age and to what extent they could maintain their competitive success to a senior age. Further committed and longitudinal research is required specific to athletes who may not have won a medal at a junior but still progress to win at a senior age and what athlete, environmental and system level factors contribute to this achievement.

Secondly, due to the limited length of the observational time for senior performance, future research is encouraged to expand the data to identify whether it differs between *junior medalists* and *early achievers in* maintaining their senior success. Besides, as the current study mainly focused on junior success at two different levels (junior/senior) to predict senior success, it has limitation in predicting athletes that participate in both junior and senior competitions at the same time. Within this study, international junior success has been confirmed as an important indicator of later international senior success, in the future studies, together with other athlete-centric factors such as technical (Sadowski et al., 2012), physical (García-Pallarés, et al., 2011), physiological, psychological and sociological variables should be considered to build a more comprehensive predictive model of senior international sporting success.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendices

Appendix 1. Summary table of existent literature exploring the junior–senior competitive relationship

Author	Title	Sports	Method	Results/conclusions
Brouwers et al. (2012)	An examination of the importance of performances in youth and junior competition as an indicator of later success in tennis	Tennis	Using a bottom-up approach to compare the success that successful junior players reached at senior competitions, and a top-down approach to examine the number of successful senior players that had won junior medals	No distinct age was found at which players should start to perform in order to be successful at the professional level. It is concluded that even though good performances at young ages increase athletes' chances to become elite players, they are not a precondition for achieving later success
Barreiros et al. (2014)	From early to adult sport success: analysing athletes' progression in national squads	Soccer, volleyball, swimming and judo	Three hundred and ninety-five athletes that competed in their national squads between 1988 and 2008 were recorded and divided into pre-junior, junior and senior groups, numbers of pre-junior selected as junior, juniors selected as senior were analysed	Results showed that only one third of international pre-junior athletes reappeared as senior athletes, confirming the difficulties of predicting late success based on early identification and selection
Brito et al. (2004)	Will best athletes as youngsters be equally best as adults?	Track and field	Retrospective data collection of women's career in the top five (Portuguese rankings), in the junior stage (under 13, 15 and 17 years old), between 1986 and 1990. A descriptive and retrospective analysis was conducted on 329 athletes till the senior stage	A small percentage of athletes that appeared among the top five athletes at an early age appeared among the five best as seniors
Schumacher, Mroz, Mueller, Schmid, and Ruecker (2006)	Success in elite cycling: a prospective and retrospective analysis of race results	Cycling	The official results of major junior (age ≤ 18 years) and elite (age > 18 years) cycling races from 1980 to 2004 were analysed. Age-related aspects, career lengths and success were compared between riders who presented results in both junior and elite races (JUNIOR ELITE) and riders who had no junior race results (ELITE ONLY). Altogether, 27,454 results of 8004 athletes from 108 countries were collected	Results show that 29.4% of the elite athletes had participated in junior World Championships, and that 34% of the participants in junior World Championships later participated in major elite competitions. Junior elite athletes are significantly more successful in several cycling disciplines and have their first and last elite result at a younger age than elite only athletes

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Continued.

Author	Title	Sports	Method	Results/conclusions
Barreiros and Fonseca (2012)	A retrospective analysis of Portuguese elite athletes' involvement in international competitions	Swimming, judo, soccer, volleyball	Four sports were selected based on their popularity and to investigate when athletes began their international involvement and the percentage of them that competed during their youth development, their average age of debut and a retrospective descriptive analysis were performed relative to sex, type of sport and level of success	Results suggest that early involvement in international events and selection of talent during early ages is not a prerequisite of success, particularly in team and male sports
Scholz (2006)	The throwing events at the IAAF World Junior Championships: A whistle stop on the journey to elite athletics	Throwing events	It covers (1) the history of the championships, (2) the role of the championships in the career development of young throwers, (3) performance comparisons, (4) anthropometric data of the throwing event participants and (5) performance development in the throwing events through the first nine editions of the championships	Findings show that success in the World Junior Championships is becoming an increasingly important prerequisite for success at the elite senior level
Güllich and Emrich (2014)	Considering long-term sustainability in the development of world class success	All Olympic Games	Collecting athletic biographies from a large sample of German national squad athletes across all Olympic sports. In a combined retrospective and longitudinal study utilising postal questionnaires, we evaluated the age at onset, volume, and domain-specificity, variability in training and competition and success attained at different ages	Developmental practice patterns leading to rapid adolescent success and long-term senior success were inconsistent, and in some aspects contradictory
Güllich (2014)	Selection and de-selection and progression of German football talent promotion	German football	The annual turnover of squad members in national junior teams (2001–2013) and youth elite academies was calculated; national U-team members were followed up with regard to nominations to their eventual success achieved at senior age; all players were analysed retrospectively regarding their earlier involvement in TID/TP programmes	The mean annual turnover of squad members was 24.5% (youth academies) and 41.0% (national U-teams) respectively. At any age, the probability of persisting in the programme three years later was <50%. Among current Bundesliga players, the age of recruitment into the TID/TP programme was evenly distributed across childhood and youth, respectively

Appendix 2. The independent and grouping variables used within the DA

| | Independent variables | | | | | | Grouping variables |
	TG	TS	TB	M. Code	Total.M	M/NoM	S. M/NoM
Participant 1	0	2	0	2	1	1	0
Participant 2	0	0	0	0	0	0	0
Participant 3	0	2	3	2	2	1	1
Participant 4	1	0	3	1	2	1	0
Participant 5	0	2	3	2	2	1	0
Participant 6	1	2	3	1	3	1	1
Participant 7	0	0	0	0	0	0	0
Participant x	0	2	3	2	3	1	1

Note: Two samples were analysed separately. TG: Total number of gold medals won at a junior age; TS: Total silver medals won; TB: Total bronze medals won; M.Code: The colour of medals (0 = no medal, 1 = gold, 2 = silver, 3 = bronze); Total.M: Total medals won; M/NoM: Athletes won medals or not (0 = no medal won, 1 = won medal); S.M/NoM: Athletes won medals or not at senior age (0 = no medal won, 1 = won medal).