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Age-related proprioceptive decline is not seen in lifelong skiing and snowboarding participants: Lessons for balanced active healthy ageing

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ABSTRACT

Objectives: Ankle proprioception is important for effective human movement and thus active healthy aging. Chronic ankle instability (CAI) may be a contributing factor in proprioception decline. Proprioception and aging research indicate that there is age-related decline in proprioception, however, most research has been on activities conducted in flat, even, and unchanging environments. Thus, to support active healthy aging theory and practice across diverse real-world environments this research explores snowsports activities that are conducted in more dynamic environments and that may be participated in across the lifespan.
Design: This research used a cohort comparison approach to study whether regular snowsport participation (i.e., skiing and snowboarding) is correlated with i) age-related proprioception decline, and ii) proprioception deficits observed with CAI.
Methods: 142 advanced and elite snowsport participants (age-range 12–70 years), were recruited over a two-year period. Participants completed a questionnaire that included: prior snowsport experience, ankle injury history and the Identification of Functional Ankle Instability scale (IdFAI). Lower limb proprioception was tested using the Active Movement Extent Discrimination Assessment (AMEDA) device.
Results: There were no significant differences in AMEDA scores between i) age categories; ii) those with or without CAI; nor iii) between females and males.
Conclusions: These results show that regular snowsport participation such as skiing and snowboarding, that occur in dynamic and changing environments, may i) protect against age-related proprioception decline, and ii) provide a rehabilitative effect for CAI. Thus, snowsport participation may be beneficial for active healthy aging and fall prevention.

1. Introduction

Sport and physical activity in older populations has been shown to support active healthy aging via better quality of life, a reduced risk of falling, and with physiological and psychosocial benefits [1]. Balance skills are also enhanced via sport and physical activity across the lifespan [2]. To maintain mobility and physical activity, balance, strength and proprioception, i.e. awareness of position, are particularly important as we age [3]. However, proprioception has been shown to decline in older individuals [4]. It is particularly worse than younger individuals when only small movements are involved [2]. Further, muscle force and power has been shown to decline after the age of 18 while balance can decline rapidly after the age of 60 [5]. Even within a healthy population power, balance, mobility, and functional movement may be lower for those aged over 30 years [4]. This suggests that as we age we will have less skill in managing small body movements, and be less aware when a movement is starting, particularly in unfamiliar environments [6,7]. Some limited health and physical activity research has demonstrated that balance and proprioception are trainable in the elderly through activities like Tai Chi, yoga and Pilates conducted on stable environments [8]. However, further evidence-based strategies are needed to maintain proprioception and balance across the lifespan to support active healthy aging, including fall prevention, in dynamic and challenging real-world environments.

Proprioception ability has been effectively measured in the ankle region using the Active Movement Extent Discrimination Apparatus (AMEDA). One study of 118 participants (aged 13–90 years) showed that

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proprioception, as measured by the AMEDA, declined with increasing age. This was particularly evident after the age when proprioception skills reach maturity (i.e., 18–25 years) [4]. Better ankle proprioception awareness was observed in athletes who achieved higher levels of sporting attainment in sports as diverse as soccer, gymnastics, badminton, swimming, and sports-dancing [9]. This relationship between sporting achievement and proprioception was also observed between different levels of professional snowsport instructors [10]. A limit of most extant proprioception research is that it focuses on activities that typically involve organized or team activities and are conducted on stable and/or flat environments e.g., gymnastics, ballet, and soccer/football [9,11]. These controlled surface qualities lack the real-world application, or ecological validity, required to live actively outside of built environments. Individuals with sustained ankle symptoms and instability after an injury are defined as having CAI [12]. Those with CAI have been shown to have chronic deficits in physical performance tests such as position sense [12,13] and postural control [14,15]. Thus, to support active healthy aging, further proprioception research is needed with physical activities that can be participated in across the lifespan, by all genders, and in a variety of environments.

Population-wide sport and exercise research demonstrates that participation in individual sports and recreation activities (e.g., walking, golf, snowsports), rather than team-based sports (e.g., football, rugby union), are more popular across the lifespan (Fig. 1). Participation in non-organized physical activities is highest in age groups over 55 years [16]. For selected physical activities (Fig. 1), those with the highest proportion in non-organized activities were activities that can be participated in individually or in small groups, e.g., walking (98% in non-organized activities), running and swimming (94% each), snowsports (86%) and aerobics/fitness (76%). In contrast, those activities with club structures, or instructor-led have lower participation than non-organized activity, e.g., aquarobics (40%), and football and rugby union (36%). This is important when trying to encourage physical activity across the lifespan, as physical activities outside of the costs and constraints of sport structures may be more accessible than competitive, timetabled activities. Thus, non-organized physical activities, such as snowsports, may have greater societal public health outcomes than formalized sport and recreation activities when whole-of-life participation and benefits are considered.

Snowsports including alpine skiing, snowboarding, telemarking and cross-country skiing are participated in around the world and include over 400 million annual skier visits for both day trippers and tourists [17]. Around 15–20% of recreational snowsports participants are aged over 55 years, and c.40% are female [16,18]. There is some evidence that participation in structured snowsport programs may have health benefits for older participants [19]. As snowsport participation typically occurs when other outdoor activities may not be available due to weather or other climatic conditions, snowsports may also be beneficial for mental health and seasonal affective disorder [20]. It is not yet known whether lifelong snowsport participation has benefits in balance and/or proprioception skill, nor whether this type of activity is beneficial for recovery from ankle injury and chronic ankle instability (CAI) that would support lifelong physical activity.

Lower limb function is central to the performance of snowsports activity, however it is also the most common injury location in skiing [21]. The extent to which CAI deficits may be influential in ongoing snowsport participation is not yet known. In active elite sport populations, CAI has not been linked with proprioception deficits, suggesting a rehabilitative effect of sports participation [22] that has also been observed in a growing body of snowsport research [10,23].

To build upon the extant research this paper explores the age group differences in proprioception scores of experienced snowsport participants. This study aimed to assess the associations between age, CAI status, and proprioception skill. The study questions were.

- Does regular snowsport activity protect against age-related proprioception decline as seen in other populations?
- Do snowsport participants with CAI exhibit proprioception deficits as seen in other populations?

The authors posited that proprioception performance would be maintained in the older lifelong snowsport participants; and that proprioception performance will not differ between snowsport participants with stable and CAI ankles.

2. Methods

Over a two-year period (2016–18) a convenience sample of advanced and elite snowsport participants (n = 142) were recruited as part of a longitudinal study on snowsport safety. Reflective of a pragmatic research design [24] testing was scheduled as early as possible in the snowsport season and to suit the work and school demands of the

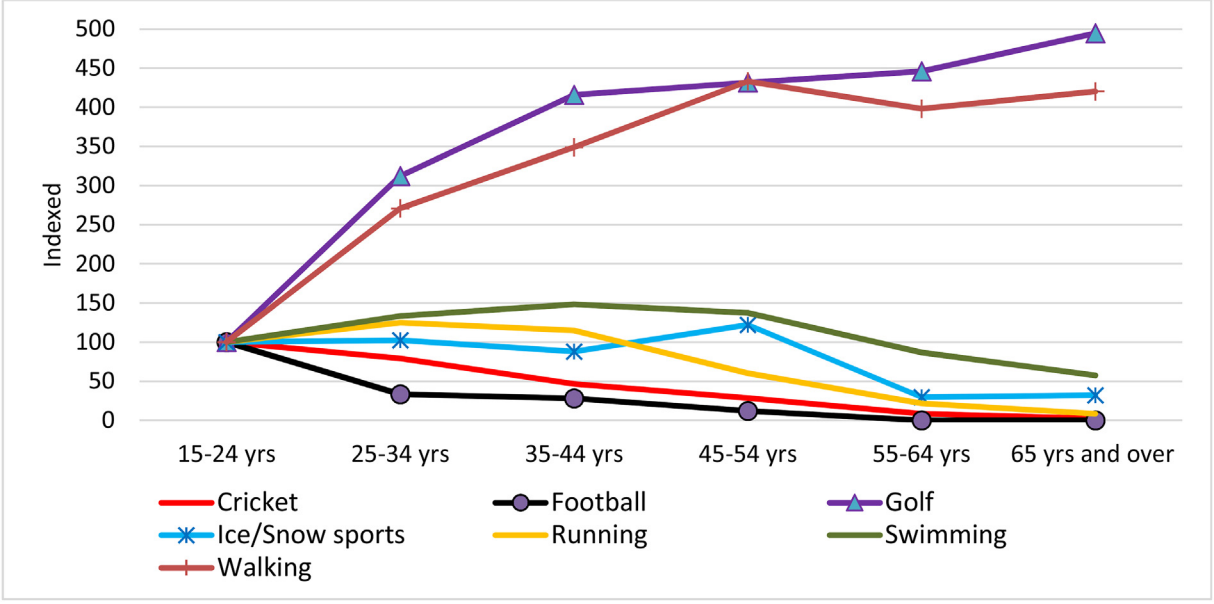

Fig. 1. Indexed participation levels in organised and non-organised sport and recreation activities, adapted from ERASS, Table 15 [16].

participants and organizations involved.

Three cohorts (mean age 25.5 years, range 12–70) completed a questionnaire that included their prior snowsport experience, their ankle injury history and the Identification of Functional Ankle Instability (IdFAI) [25]. Lower limb proprioception was tested using the Active Movement Extent Discrimination Assessment (AMEDA) apparatus [4] (Fig. 2). Collectively participants had 2580 years of skiing experience ($\bar{x}$ = 21.5 years, SD = 14.1) and 654 years of snowboarding experience ($\bar{x}$ = 8.1 years, SD = 5.4).

Cohort 1, recruited in early December 2016, included 75 snowsport instructors from a western Canadian snowsport resort (16–75 years, $\bar{x}$ = 39.1, SD = 16.1). They had a total of 1740 years of skiing experience ($\bar{x}$ = 25.6 years, SD = 14.7) and 388 years of snowboarding experience ($\bar{x}$ = 8.8 years, SD = 6.2). Cohort 2, recruited in July 2018, included 21 elite high-school aged snowsport participants (12–17 years, $\bar{x}$ = 14.4, SD = 1.4) involved in an Australian school-based snowsport program. They had a total of 119 years of skiing experience ($\bar{x}$ = 10.8 years, SD = 3.6) and 84 years of snowboarding experience ($\bar{x}$ = 6 years, SD = 2.1). Cohort 3, recruited in December 2018, was 59 snowsport instructors from a western Canadian snowsport resort (17–70 years, $\bar{x}$ = 29.5, SD = 15.4). They had a total of 985 years of skiing experience ($\bar{x}$ = 18.6 years, SD = 12.7) and 234 years of snowboarding experience ($\bar{x}$ = 8.7 years, SD = 5.2). 9 of these participants were also tested in 2016. Participants were excluded if complete data was not available (n = 13). The research was approved by both the University of Canberra Human Research Ethics Committee and the Thompson Rivers University Research Ethics Board.

The AMEDA is a novel test that has been demonstrated to be effective to assess intrinsic lower limb proprioception across a range of sporting activities from recreational to elite participation, and from younger to older participants [4,9,10,23]. The AMEDA has one fixed and one movable platform; participants place one foot upon each platform in full weight-bearing stance, with their head held up and the gaze straight ahead (Fig. 2). The foot on the moveable platform is positioned along the axis, and an electronic system enables the limit for platform tilt to be randomly set to five possible ankle inversion positions. A familiarization process precedes the test. Participants actively tip the platform to each of the 5 inversion depths, in sequence from 1 to 5, three times, to experience the positions. During testing the platform limit is set randomly to one of the 5 positions, with a total of 50 trials. The participant actively moves the platform to the limit and is asked to identify the position. A proprioception score is calculated by how accurately participants recognize the platform resting position over the 50 trials [4].

Data was entered into SPSS 24.0 for analysis. Ages were recoded into 4 groups for further analysis. To explore the appropriateness of the retrospective data combination of the three cohorts, Chi-square tests were conducted. Analysis included descriptive statistics, while Chi-square tests for independence, Pearson product moment and ANOVA were used to explore between-group differences.

Fig. 2. Active Movement Extent Discrimination Assessment device (AMEDA).

3. Results

3.1. Data combination

There was no difference in the three cohorts for gender mix; a Chi-square test for independence indicated no significant association between gender and membership of the three cohorts, $\chi 2$ (1, n = 142) = 0.90, p = .64. As expected, there was a significant difference between cohorts across age groups, as Cohort 2 was a youth-only group $\chi 2$ (1, n = 142) = 122.13, p < .001. Thus, combination of the data was considered appropriate to enable cohort comparisons.

3.2. Gender and age

An independent sample t-test did not show a significant difference between the AMEDA scores of the 63 females ($\bar{x}$ = 0.65, SD = 0.05) and 79 males ($\bar{x}$ = 0.68, SD = 0.05 t (140) = -2.69, p = .58). The relationship between age and proprioception scores, as measured by the AMEDA, was investigated using Pearson product–moment correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity, and homoscedasticity. There was no correlation between the two variables, age and AMEDA scores, $r = -0.012$, $n = 142$, $p = .892$. This is explored further below under age-related decline (see Table 1).

3.3. Snowsports: role and disciplines

The two main roles of participants were school student and snowsport instructor. An independent sample t-test did not show a significant difference between the AMEDA scores of the 21 school-based participants ($\bar{x}$ = 0.65, SD = 0.05) and the 121 instructors ($\bar{x}$ = 0.67, SD = 0.05, t (140) = -1.76, p = .91). To investigate the impact of prior experience in difference snowsport disciplines upon proprioception scores participants were divided into three groups based upon their snowsport experience (Group 1: alpine skiing only (n = 61); Group 2: snowboarding only (n = 17); Group 3: both skiing and snowboarding (n = 64)). A one-way between-groups analysis of variance (ANOVA) indicated that there was no statistically significant difference at p < .05 level in AMEDA scores for the three discipline groups: F (2, 139) = 0.05, p = .95 (see Table 1).

3.4. Age-related proprioception decline

The explore whether snowsports are preventative against age-associated loss of proprioception, as measured by the AMEDA, participants were divided into four age groups. Group 1: less than 19 years (n = 25); Group 2: 19–39 years (n = 81); Group 3: 40–59 years (n = 19); Group 4: 60 years+ (n = 17). An ANOVA indicated there was no statistically significant difference at the p < .05 level in AMEDA scores for the four age groups: F (3,138) = 1.3, p = .27 (see Table 1).

3.5. Chronic ankle instability (CAI)

The second research question was whether CAI was associated with proprioception deficits. At the time of testing 78 (55%) reported having had a prior ankle injury that restricted their normal activities for more than 7 days. Of these, 33 (42%) had a functionally unstable ankle, i.e., IdFAI>11. An independent sample t-test did not show a significant difference between the AMEDA scores of the 33 with a functionally unstable ankle ($\bar{x}$ = 0.68, SD = 0.04) compared with the 45 without ($\bar{x}$ = 0.66, SD = 0.06, t (76) = −1.34, p = .18).

3.6. Factors correlated with AMEDA scores

A three-way ANOVA was conducted to further explore the interaction of different factors upon AMEDA scores. A statistically significant interaction was revealed for gender, age group and IdFAI on AMEDA scores, F

Table 1
Socio-demographics of three cohorts (n = 142).

	Cohort 1 Instructors (2016) n = 66 (%)	Cohort 2 Youth (2018) n = 21 (%)	Cohort 3 Instructors (2018) n = 55 (%)	All n = 142 (%)
Gender				
Female	32 (49%)	9 (43%)	22 (40%)	63 (44%)
Male	34 (51%)	12 (57%)	33 (60%)	79 (56%)
Age Range (Mean, SD)	16-75 (38.1, 15.7)	12-17 (14.4, 1.4)	17-70 (30.2, 15.7)	12-75 (31.4, 16.5)
Age groups				
< 19 years	1 (1%)	21 (100%)	3 (5%)	25 (18%)
19–39 years	40 (61%)	0	41 (75%)	81 (57%)
40–59 years	15 (23%)	0	4 (7%)	19 (13%)
60 years plus	10 (15%)	0	7 (13%)	17 (12%)
Activity experience				
Alpine skiing: Range (Mean, SD)	1–63 years (25.4, 14.9)	1–14 years (10.8, 3.6)	1–62 years (19.1, 13)	1-62 (21.5, 14.1)
Snowboarding: Range (Mean, SD)	1–22 years (8.4, 6.3)	3–10 years (6.0, 2.2)	1–24 years (8.7, 5.2)	1-24 (8.1, 5.4)

(3,62) = 3.201, $p = .029$ (Table 2). Where both sub-groups had n > 1, only one (males aged 19–39 years) did not obtain higher mean AMEDA scores for those with functional ankle instability (IdFAI>11) than those without ankle instability. There was no significant interaction for the four age groups, the three snowsport discipline groups and IdFAI, $F(2,60) = 2.951$, $p = .06$.

4. Discussion

The dominant sport, health and exercise narrative is that as people age there is an associated decline in physical performance, including balance, of which one component is proprioception. This presents a societal and public health challenge as to how to support active healthy aging as we live longer. To explore this problem this research drew upon a convenience sample of active snowsport participants where it is demonstrated that people continue to participate well into their old age [5,16,18]. Previous proprioception research studied participants in sport and physical activity that typically involves flat, predictable, firm, or hard surfaces such as for football, tai chi, badminton, and even ballet [4,6,8]. In contrast, snowsports involve sliding across unpredictable environments that constantly vary in incline, camber, and smoothness, and frequently involve movement across these dynamic environments at speeds exceeding 40 km/h [26–28].

Table 2
Three-way ANOVA for those with prior ankle injury history (n = 78).

Gender	Age Group	Functionally Unstable Ankle (IdFAI >11)	n	AMEDA mean score	Std. Dev.	If IdFAI>11, AMEDA mean score higher
Female	<19 years	No	1	0.6700	.	
		Yes	2	0.6750	0.04	N/A
	19–39 years	No	12	0.6250	0.06	
		Yes	10	0.6820	0.04	Yes
	40–59 years	No	3	0.6700	0.05	
		Yes	1	0.5800	.	N/A
	60 years plus	No	3	0.6400	0.03	
		Yes	2	0.6600	0.00	Yes
	Total	No	19	0.6368	0.06	
		Yes	15	0.6713	0.05	Yes
Male	<19 years	No	2	0.6200	0.10	
		Yes	1	0.7200	.	N/A
	19–39 years	No	17	0.6947	0.05	
		Yes	14	0.6807	0.03	No
	40–59 years	No	5	0.6780	0.05	
		Yes	2	0.7150	0.01	Yes
	60 years plus	No	2	0.6650	0.02	
		Yes	1	0.6800	.	N/A
	Total	No	26	0.6835	0.06	
		Yes	18	0.6867	0.03	Yes

The results from this research showed no difference in proprioception scores between snowsport disciplines (i.e., alpine skiers and snowboarders); nor between the two nominated genders; nor between 4 age groups; and no difference between high school-based elite participants versus professional snowsport school instructors. Counterintuitively, there was a difference in those with functional ankle instability, who typically earned higher proprioception scores, than those without a functionally unstable ankle. In contrast to previous research [4,8] this sample did not demonstrate the same level of age-related decline in proprioception, and in fact showed no significant difference between the proprioception scores across the four age groups.

Further, while previous research has indicated that chronic ankle instability (CAI) is associated with deficits in physical performance tests like position sense and postural control [14,15], the 33 participants identified as having a functionally unstable ankle (i.e. IdFAI>11), showed no decline in proprioception scores. Frequently they demonstrated better scores than those who did not as have a functionally unstable ankle when analyzed by gender, age group and snowsport discipline. It is possible that individuals who have CAI and continue to participate in snowsports achieved this by compensating for the physical deficits that may affect balance or power, through this increased proprioception around the unstable ankle. A similar effect has recently been reported in active military personnel [29]. Further study is needed to assess the mechanisms that support these individuals with identified CAI, who nevertheless manage to cope with the dysfunction and maintain their sporting participation.

The conflicting findings of this research raises the possibility that snowsports such as alpine skiing and snowboarding may have a training and/or rehabilitation effect that is not available in other more researched sport and physical activities. This has implications for research and practice in active healthy aging, and the rehabilitation of lower limb injuries. Further research is necessary to determine whether the uneven, changeable, and dynamic environment in which snowsports are performed provides a proprioceptive training effect that cannot be duplicated in the gymnasium or on the field. The potential benefits for lifelong snowsports participants include the prevention of age-related decline in proprioception, contribution to a rehabilitation in CAI and thus supporting active lifestyles across the lifespan.

5. Limitations and future research

Limitations are inherent in pragmatic exploratory research designs using a convenience sample such as this. To extrapolate findings to a general population of active older adults a larger sample size would be required. The findings relating to CAI may be indicative of a survivor bias in the selection. Since all participants were advanced to expert skiers or snowboarders the results cannot be generalized to a broader snowsport population. A longitudinal prospective study would require

considerable resources, but could resolve questions over survivor bias and enable the inclusion of a variety of control groups and co-variants. A comparative group of older adults who maintain their fitness in indoor, flat, predictable environments would be illuminating as would interrogation of off–season activity and snowsport preparation. Proprioception testing could be complemented with activity tracking as is increasingly available via wearable fitness devices that could provide additional data such as heart rate, exercise intensity, frequency and duration, and sleep patterns [23].

6. Conclusion

This novel and exploratory research focused upon snowsports where participants can participate across their lifespan. In contrast to most physical activity and proprioception research, this research focused on an activity where the environment is dynamic, variable, and cognitively challenging. The results suggests that regular snowsport participants do not demonstrate the same age-related decline in physical performance seen in other research [4].

Insight from this research highlights the need to investigate the benefits for active healthy aging and return to play from injury of a range of sports and physical activities that can be participated in across the lifespan and in diverse physical environments. Future research in other whole-of-life organized and non-organized activities may be beneficial in prescribing other suitable activities that address the physical and mental health needs of our aging populations. This may also include loss of muscle bulk; loss of bone strength, reduced visual acuity, and generalised reduction of neurological function/speed. Emerging activities that may be of interest include stand-up paddle boarding and mountain biking, particularly with E-bikes [30].

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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