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Use of dietary supplements in differently physically active adolescents

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Summary

Aim of our study was to determine whether the extent of physical activity and sports-club membership affect the prevalence and frequency of dietary supplement (DS) use. Data were obtained within the Slovenian ACDSi-2014 cross-sectional study. Adolescents (14–19 years old) enrolled in 15 public secondary schools ($N = 1463$) were included in a nationally representative study sample. Average daily energy expenditure for physical activity (DEEPA) was determined with School Health Action, Planning and Evaluation System questionnaire. DS data were collected with purposely prepared questionnaire. Our results indicated that more than two-thirds (69 %) of adolescents used DS, when DS users were defined as anyone using DS at least several times per year. However, if DS users were defined differently, i.e. according to their frequency of DS use, the prevalence changed considerably, namely to 52 %, 40 %, and 14 %, for those using DS at least once per month, week, or day, respectively. With higher average DEEPA and sports-club membership, DS use increased significantly. A comparison of different prevalence of DS use related to different frequency of DS use demonstrated a big discrepancy between these prevalence estimations, which points to an urgent need for a methodological standardization of data acquisition regarding DS use.

Keywords

dietary supplementation; physical activity; adolescent; standardization; organized sports

Balanced diet along with sufficient physical activity is recommended for maintaining health and well-being [1]. Although sports participation may increase the need for some vitamins and minerals in athletes [2], a balanced diet with adequate energy intake provides all the necessary nutrients [1]. Consequently, the use of dietary supplements (DS) to enhance sport performance is neither endorsed nor recommended [1, 3].

Despite this, DS use has become widespread in adolescents, in particular in athletes [3–8], with the reported prevalence of up to 91 % in elite athletes [5]. Some studies found that certain supplements may have positive effects on sport performance [2] and may reduce disease risks [9], but most studies do not support the claims of beneficial effects of the majority of DS [10]. Certain DS have even been associated with adverse effects [11].

Due to the abovementioned issues, the increase in DS use among all age groups is alarming, particularly in adolescents, who are often the most susceptible and misinformed customers [12]. It is difficult to indicate an average prevalence of DS use for any population group, as it depends on a number of socio-demographic [4, 6, 7, 13, 14] and lifestyle factors [5, 14–17]. A large majority of studies that investigated DS use among adolescents focused on (elite) athletes and revealed large variability in prevalence of DS use, between 22 % and 91 % [3–5, 15, 16, 18–23]. Studies on general child and adolescent populations indicated smaller yet also very variable prevalence, between 15 % and 58 % [6, 8, 13, 14, 17, 24–33].

Also, although DS use was extensively investigated in both athlete and non-athlete adolescents, there is almost a complete lack of studies examining the prevalence of DS use among adolescents in relation to the their physical activity extent; we

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managed to identify only two such studies in athletes [5, 15] and two in general population [8, 17]. Thus, we aimed to 1) determine the prevalence of use for different types of DS in secondary school adolescents for the different frequencies of their use, 2) to determine the prevalence of DS use in relation to adolescents' physical activity extent.

MATERIALS AND METHODS

Study design and study sample

Data were obtained within a wider, ACDSi 2014, cross-sectional study [34]; a detailed description of its methodology was published elsewhere [34]. In short, the ACDSi 2014 study sample was selected with a two-stage clustered and stratified sampling procedure. At the first stage, 16 out of the existing 170 secondary schools were selected according to the secondary school educational programme and school location. At the second stage, a required number of classes from each school were randomly selected for participation. Finally, students of these classes were invited to voluntarily participate in the study. Before participation, written informed consent was obtained from all participants. The entire population of secondary-school students in 2014 in Slovenia was 75 325, and the required size of the sample to assure the national representativeness was estimated to be 384 students (with a confidence interval of 0.95).

Final study sample of the present study included participants enrolled in 15 public secondary schools in Slovenia (one of the initially selected schools was excluded, due to insuffitient response rate of the participants), about 200 males and 200 females from each of the four years of secondary school education. Consequently, participants were 14–19 years old, thus at the age that, according to the World Health Organization definition, belonged to the middle adolescence stage [35]. The study was approved by the Ethics Committee of the Republic of Slovenia.

Data collection

Data about DS use were collected with a guided, purposely designed e-questionnaire. Participants responding "Yes" to the question "Do you occasionally use DS?" were then asked to indicate the type (vitamin, mineral, multivitamin/multimineral (MVMM), proteins/amino acid, fats/fatty acid) and frequency (1–3 times per year, 4–11 times per year, 1–3 times per month, 1–3 times per week, 4–6 times per week, every day, more than once daily) of DS use in the past year. According to the frequency of DS use we defined four types of DS users: those using DS (i) at least several times per year, (ii) at least once per month, (iii) at least once per week, and (iiii) at least once per day (= daily users). In addition, those participants, who used DS at least once per week, were defined as regular users.

The physical activity extent was determined with an e-questionnaire adapted from School Health Action, Planning and Evaluation System (SHAPES) physical activity questionnaire [36]. We used two items from this questionnaire: 7-day recalls of vigorous physical activity (VPA) and moderate physical activity (MPA).

The average daily physical activity (in hours) was calculated according to the approach of Wong and Leatherdale [37], as was the average daily energy expenditure for physical activity (DEEPA) expressed in kilojoules per kilogram of body mass per day. Average DEEPA was then used to classify the participants to less active (LA), moderately active (MA) and vigorously active (VA), as recommended by Wong and Leatherdale [37]. Namely, participants whose average DEEPA was 1 standard deviation (*SD*) below the sample mean ($\leq$ 16th percentile) were classified as inactive. Similarly, participants whose average DEEPA was 1 *SD* above the sample mean ($\geq$ 84th percentile) were classified as vigorously active. Finally, the rest, i.e. the participants whose average DEEPA was within 1 *SD* of the sample mean (thus within 17th to 83rd percentile), were classified as moderately active. Thus, the adolescents in our sample, whose average DEEPA was below 13.4 $kJ \cdot kg^{-1} \cdot d^{-1}$, were classified as LA (N = 229; 80 males, 149 females); if their DEEPA was above 56.3 $kJ \cdot kg^{-1} \cdot d^{-1}$, they were classified as VA (N = 231; 176 males, 55 females); and if their DEEPA was between 13.8 $kJ \cdot kg^{-1} \cdot d^{-1}$ and 55.7 $kJ \cdot kg^{-1} \cdot d^{-1}$, they were classified as MA (N = 985; 467 males, 518 females).

In addition, two categories were formed according to sports-club membership: non-athletes (non-members) and athletes (members). The questionnaire included further questions about weekly time spent in training within the sports-clubs (less than 1 h per week, 1–2 h per week, 3–4 h per week, 5–6 h per week, 7–13 h per week, more than 14 h per week).

Statistical analysis

All data were analysed with IBM SPSS Statistics 22 (IBM, Armonk, New York, USA).

Descriptive data were presented as average ± *SD* and/or as prevalence of DS use (in percent). Statistical analysis was performed with Chi-square test and either independent *t*-test or analysis of variance. Chi-square trend was noted where applicable. The level of statistical significance was set to 0.05.

To analyse the frequency of DS use, we classified the users into four different groups according to the frequency of their DS use (i.e. the use of DS at least several times per year, at least once per month, at least once per week and at least once per day). The prevalence of DS use was then determined for overall DS users (i.e. subjects using any type of DS) and for users according to an individual type of DS (i.e. subjects using a specific type of DS) for each of the four groups.

Several sets of comparisons were then performed.

(I) To analyse the effect of physical activity extent and sports-club membership on DS use, we compared the prevalence of DS use between LA, MA and VA, as well as between non-athletes and athletes for all four frequencies of use. In addition, the prevalence of more regular users (i.e. those using DS at least once per week) was compared between LA, MA and VA, as well as between non-athletes and athletes. For athletes who were regular users, the analysis was further subdivided into three categories according to the weekly time spent training in sports club (≥ 2 h per week, 3–6 h per week, ≤ 7 h per week).

(II) To analyse the effect of physical activity extent, sports-club membership and gender on multiple DS use (i.e. simultaneous use of at least two different types of DS), we compared the prevalence of DS use and the average number of different DS used in relation to physical activity, between non-athletes and athletes, and for males and females separately.

RESULTS

The questionnaires were completed by 81.5 % of the participants, thus the final study sample included 1479 adolescents. After excluding participants aged 20 years or older ($N = 16$), the analysed sample included 1463 adolescents (735 males, 728 females) aged 14–19 years. The number of participants who provided all the necessary answers for the physical activity extent calculation was 1445. Out of 1443 participants, who provided the answer about their potential sports-club membership, 466 were sports-club members, with significantly more males ($p < 0.001$; $N = 296$) than females ($N = 170$).

The average DEEPA in each of the three studied groups was 6.7 ± 4.6 kJ·kg^{-1}·d^{-1} for males and 8.4 ± 3.8 kJ·kg^{-1}·d^{-1} for females in the LA group, 34.3 ± 12.1 kJ·kg^{-1}·d^{-1} for males and 30.1 ± 11.3 kJ·kg^{-1}·d^{-1} for females in the MA group, and 72.8 ± 16.3 kJ·kg^{-1}·d^{-1} for males and 70.3 ± 10.5 kJ·kg^{-1}·d^{-1} for females in the VA group.

Association between adolescents' dietary supplement use and their physical activity

The effects of physical activity extent on DS use are presented in Tab. 1 and Tab. 2. Our results demonstrated that prevalence of DS use changed considerably with physical activity extent, specifically between the three groups with different average DEEPA (i.e. LA, MA, VA) (Tab. 1). These results indicate significantly higher prevalence of DS use in adolescents with higher average DEEPA.

The effects of sports-club membership on DS use are presented in Tab. 2, demonstrating in both genders a significantly higher prevalence of DS use in athletes, as compared to non-athletes, irrespective of their classification according to the frequency of DS use. Gender-specific analysis revealed highly significant differences in DS use between non-athletes and athletes in males for each DS type except fats/fatty acids. In females, these differences were significant for overall DS use, vitamins and proteins/amino acids.

Detailed analysis of individual types of regular DS users (i.e. those using DS at least once per week, $N = 569$) revealed a significant positive relation between physical activity extent and prevalence of DS use in males ($p < 0.01$) for each individual type of DS (Tab. 3). In females, this relation was non-significant, although the increasing trend was evident and similar for both minerals and proteins. Additional analysis among athlete DS users (329 males, 240 females) demonstrated that DS use among adolescents was not associated with weekly time spent in training ($p = 0.61$ in males, $p = 0.15$ in females).

Multiple dietary supplement users

Several adolescents used more than one type of DS (Tab. 4). For those using DS several time per year, once per month, week, or day, the observed prevalence of multiple DS users was 49 %, 34 %, 24 %, and 6 %, respectively. The prevalence of multiple DS users also increased with higher average DEEPA, highly significantly in males, but not in females, for all frequencies of DS use. The results indicated the use of 2–3 different DS on average. The average number of different DS consumed was not associated with higher average DEEPA. When non-athletes and athletes were compared, similar results were observed (Tab. 5).

Tab. 1. Prevalence of dietary supplement use in adolescents with different physical activity extent.

	Prevalence [%]																			
	At least several times per year					At least once per month					At least once per week					At least once per day				
	LA	MA	VA	*p*	p_1	LA	MA	VA	*p*	p_1	LA	MA	VA	*p*	p_1	LA	MA	VA	*p*	p_1
Males/Females (*N* = 1445)	151	673	179			85	498	153			56	387	126			19	132	55		
Dietary supplements	66	68	78*	0.011	0.007	37*	51	66*	0.000	0.000	25*	39	55*	0.000	0.000	8*	13	24*	0.000	0.000
Vitamins	41	44	55*	0.010	0.006	27	29	45	0.000	0.000	16*	21	35*	0.000	0.000	6	8*	14*	0.000	0.000
Minerals	38	43	57*	0.000	0.000	20	28	44	0.000	0.000	12*	20	33*	0.000	0.000	4	6	7	0.001	0.000
MVMM	37*	44	56*	0.000	0.000	21	30	44	0.000	0.000	15*	18*	31*	0.000	0.000	3	4	10*	0.000	0.000
Proteins/Amino acids	20*	27	4*	0.000	0.000	11	20	33	0.000	0.000	6*	15	28*	0.000	0.000	1*	4	12*	0.000	0.000
Fats/Fatty acids	27*	33	45*	0.000	0.000	15	20	33	0.000	0.000	6*	12	23*	0.000	0.000	2	3	7*	0.000	0.000
Males (*N* = 723)	52	321	138			27	259	122			20	204	105			6	65	47		
Dietary supplements	65	69	78*	0.028	0.011	34*	56	69*	0.000	0.000	25*	44	60*	0.000	0.000	8*	14*	27*	0.000	0.000
Vitamins	32*	44	55*	0.006	0.001	27	32*	46*	0.001	0.000	15*	25	38*	0.001	0.000	8	7	15*	0.000	0.000
Minerals	38	45	57*	0.009	0.003	18*	32*	47*	0.001	0.000	17	23*	36*	0.002	0.000	2	5	9*	0.005	0.000
MVMM	36*	47	58*	0.008	0.002	21*	35	47*	0.002	0.000	17	23*	35*	0.001	0.000	5	5	10*	0.004	0.000
Proteins/Amino acids	27	37	46*	0.018	0.005	18*	30	40*	0.004	0.000	14*	23	34*	0.002	0.000	2*	7*	15*	0.000	0.000
Fats/Fatty acids	32	39	49*	0.025	0.007	15*	27	35*	0.016	0.001	6*	17	26*	0.002	0.000	3	3	8*	0.010	0.001
Females (*N* = 722)	99	352	41			58	239	31			36	183	21			13	67	8		
Dietary supplements	66	68	75	0.536	0.348	39	46	56	0.071	0.023	24*	35	38	0.028	0.013	9	13	15	0.329	0.154
Vitamins	45	45	55	0.363	0.440	26	27	40	0.319	0.251	16	18	27	0.430	0.203	5	7	9	0.624	0.290
Minerals	38	41	56*	0.065	0.055	20	24	35	0.265	0.043	10*	18	22	0.100	0.024	5	6	4	0.214	0.153
MVMM	38	42	50	0.314	0.151	22	25	33	0.503	0.087	14	14	18	0.566	0.183	3	4	9	0.174	0.057
Proteins/Amino acids	17	18	27	0.211	0.167	8	12	11	0.130	0.171	2*	8	9	0.071	0.048	1	2	2	0.492	0.142
Fats/Fatty acids	25	28	33	0.467	0.229	15	15	15	0.598	0.437	6	8	11	0.739	0.165	1	2	4	0.697	0.168

N – number of participants, MVMM – multivitamin/multimineral supplements, LA – less active, MA – moderately active, VA – vigorously active.
Significance results obtained with Chi square test between different groups of physical activity extent are presented as exact *p*-values, p_1 – Chi-square trend, * – the prevalences that significantly differed from others.

Tab. 2. Prevalence of dietary supplement use between non-athlete and athlete adolescents.

	Prevalence [%]															
	At least several times per year				At least once per month				At least once per week				At least once per day			
	All	NA	A	*p*	All	NA	A	*p*	All	NA	A	*p*	All	NA	A	*p*
Males/Females (*N* = 1443)	996	640	356		745	456	289		574	338	236		207	123	84	
Dietary supplements	69	66	76	0.000	52	47	62	0.000	40	35	51	0.000	14	13	18	0.006
Vitamins	45	42	52	0.000	31	27	40	0.000	23	19	30	0.000	8	7	10	0.000
Minerals	45	42	50	0.006	29	25	38	0.000	21	17	29	0.000	6	5	7	0.003
MVMM	45	43	51	0.003	31	27	38	0.000	20	16	27	0.000	5	4	7	0.001
Proteins/Amino acids	28	25	36	0.000	21	17	29	0.000	16	12	23	0.000	5	3	8	0.000
Fats/Fatty acids	34	32	39	0.013	21	19	25	0.028	13	11	17	0.003	3	3	3	0.051
Males (*N* = 721)	507	275	232		415	215	200		332	163	169		118	50	68	
Dietary supplements	70	65	78	0.000	58	51	68	0.000	46	38	57	0.000	16	12	23	0.000
Vitamins	45	41	52	0.004	35	28	44	0.000	27	21	35	0.000	9	6	13	0.000
Minerals	47	44	52	0.035	34	27	45	0.000	25	19	35	0.000	5	3	9	0.000
MVMM	49	46	54	0.058	37	31	45	0.001	25	19	34	0.000	6	4	9	0.006
Proteins/Amino acids	39	35	44	0.030	31	26	39	0.002	25	20	31	0.001	8	5	12	0.000
Fats/Fatty acids	41	39	44	0.128	28	26	30	0.263	18	16	21	0.130	4	4	5	0.270
Females (*N* = 722)	489	365	124		330	241	89		242	175	67		89	73	16	
Dietary supplements	68	66	73	0.096	46	44	52	0.047	34	32	39	0.063	12	13	9	0.186
Vitamins	45	43	52	0.034	28	26	31	0.209	17	18	21	0.209	7	7	5	0.075
Minerals	42	41	46	0.200	24	23	27	0.499	17	16	18	0.542	6	7	4	0.103
MVMM	41	40	47	0.108	25	25	27	0.268	14	14	15	0.236	4	4	4	0.243
Proteins/Amino acids	19	17	24	0.026	11	10	14	0.098	7	6	8	0.104	2	2	2	0.090
Fats/Fatty acids	28	27	30	0.558	15	14	16	0.883	8	7	11	0.397	2	3	1	0.561

N – number of participants, MVMM – multivitamin/multimineral supplements, NA – non-athletes (non-members of sports clubs), A – athletes (sports club members).
Significance results obtained with Chi-square test between the non-athletes and athletes groups are presented with exact *p*-values.

Tab. 3. Prevalence of dietary supplement use in regular users.

	Prevalence of users, who use dietary supplements more than once per week [%]												
	Average DEEPA					Non-athletes vs athletes			Weekly time spent in training among athletes				
	LA	MA	VA	*p*	p_1	NA	A	*p*	≤ 2 h	3-6 h	≥ 7 h	*p*	p_1
Males (*N* = 723)	20	204	105			163	169		49	77	64		
Dietary supplements	25	44	60	0.000	0.000	38	57	0.000	54	52	59	0.607	0.425
Vitamins	15*	25	38*	0.001	0.000	21	35	0.000	32	31	41	0.135	0.423
Minerals	17	23*	35*	0.002	0.000	19	35	0.000	40	30	36	0.662	0.810
MVMM	17	23*	35*	0.001	0.000	19	34	0.000	28	33	34	0.796	0.293
Proteins/Amino acids	14*	23	35*	0.002	0.000	20	31	0.001	32	32	29	0.679	0.343
Fats/Fatty acids	6*	17	26*	0.002	0.000	16	21	0.130	26	19	22	0.622	0.882
Females (*N* = 722)	36	183	21			175	67		27	36	14		
Dietary supplements	24	35	38	0.028	0.013	32	39	0.063	26	42	44	0.150	0.080
Vitamins	16	18	27	0.430	0.203	18	21	0.209	11	20	22	0.526	0.162
Minerals	10*	18	22	0.100	0.024	16	18	0.542	13	18	22	0.890	0.426
MVMM	14	14	18	0.566	0.183	14	15	0.236	9	13	22	0.589	0.312
Proteins/Amino acids	2*	8	9	0.071	0.048	6	8	0.104	7	11	7	0.377	0.435
Fats/Fatty acids	6	8	11	0.739	0.165	7	11	0.397	7	11	11	0.663	0.696

N – number of participants, MVMM – multivitamin/multimineral supplements, DEEPA – daily average energy expenditure of physical activity, LA – less active, MA – moderately active, VA – vigorously active.
Significance results obtained with Chi square test are presented as exact *p*-values, p_1 – Chi-square trend, * – the prevalences that significantly differed from others.

Tab. 4. Prevalence of multiple dietary supplement use.

	Prevalence of users, who use more than one type of dietary supplements [%]								
	N	At least several times per year		At least once per month		At least once per week		At least once per day	
		Males	Females	Males	Females	Males	Females	Males	Females
		382	327	297	191	225	118	54	36
Average DEEPA	948								
Less active	129	34*	40	21	23	14	12	3	3
Moderately active	649	53	45	40	26	29	17	7	6
Vigorously active	170	63*	62	53*	36	44*	25	12*	7
p		0.013	0.408	0.000	0.240	0.000	0.147	0.002	0.601
p_1		0.000	0.033	0.000	0.052	0.000	0.015	0.000	0.147
Non-athletes vs athletes	961								
Non-athletes	617	49	44	35	26	25	16	5	6
Athletes	344	61	50	52	28	41	18	11	2
p		0.001	0.108	0.000	0.124	0.000	0.366	0.002	0.306

N – numbers of participants, DEEPA – daily average energy expenditure for physical activity.
Significance results obtained with Chi square test are presented as exact *p*-values, * – the prevalences that significantly differed from others.

Tab. 5. Average number of dietary supplements among multiple dietary supplement users.

		Average number of dietary supplements among users who use more than one type of dietary supplement							
	N	At least several times per year		At least once per month		At least once per week		At least once per day	
		Males	Females	Males	Females	Males	Females	Males	Females
		479	469	408	328	329	240	118	89
Average DEEPA	948								
Less active	129	2.8 ± 1.6	2.5 ± 1.4	2.5 ± 1.5	2.2 ± 1.3	2.3 ± 1.4	1.9 ± 1.1	2.0 ± 1.8	1.6 ± 1.2
Moderately active	649	3.1 ± 1.5	2.6 ± 1.4	2.8 ± 1.5	2.2 ± 1.3	2.5 ± 1.4	1.9 ± 1.2	1.9 ± 1.2	1.6 ± 0.9
Vigorously active	170	3.3 ± 1.5	3.0 ± 1.4	3.1 ± 1.6	2.4 ± 1.4	2.8 ± 1.5	2.3 ± 1.3	2.1 ± 1.5	1.9 ± 1.4
p		0.187	0.159	0.054	0.874	0.092	0.283	0.809	0.746
Non-athletes vs athletes	961								
Non-athletes	617	3.2 ± 1.5	2.5 ± 1.4	2.7 ± 1.5	2.3 ± 1.3	2.5 ± 1.5	2.0 ± 1.2	1.9 ± 1.3	1.7 ± 0.9
Athletes	344	3.0 ± 1.5	2.7 ± 1.5	3.0 ± 1.5	2.2 ± 1.4	2.7 ± 1.5	1.8 ± 1.2	2.1 ± 1.4	1.6 ± 1.3
p		0.164	0.174	0.068	0.673	0.118	0.479	0.452	0.906

Values represent average ± standard deviation.
N – number of participants, DEEPA – daily average energy expenditure of physical activity.
Significance results obtained with a one-way analysis of variance (between the 3 groups according to DEEPA) and with Student's *t*-test (between the two groups according to sports club membership) are presented as *p*-values.

DISCUSSION

The aim of our study was to determine whether the physical activity extent and sports-club membership affect the prevalence and frequency of DS use. Our results revealed that more than two-thirds (69 %) of adolescents used DS, when DS users were defined as anyone using DS at least several times per year. However, when other frequencies of DS use were used to define DS users, the observed prevalence changed considerably, specifically to 52 %, 40 %, and 14 %, for those adolescents using DS at least once per month, at least once per week, or at least once per day, respectively.

This provides a direct explanation of the large differences in the prevalence of DS use reported in previous studies [5, 8]. Previously reported prevalence of DS use in adolescents, both athletes and non-athletes, ranged from 15 % [8] up to 91 % [5]. Despite the fact that different countries and sub-populations of adolescents were investigated, these large differences seem rather unrealistic. The present study provides firm evidence that frequency of DS use is a factor with considerable impact on final results and should not be neglected as in most previous studies, as this led to a large variability in previously reported prevalence of DS use. Obviously, if frequency of DS use is disregarded, comparisons between different studies on DS use become very unreliable. Indeed, a recent systematic review and meta-analysis on the prevalence of DS use in athletes [38] concluded that the lack of homogenity among studies makes is rather difficult to draw generalized conclusions on DS use between different groups of athletes.

Our results also demonstrated that higher physical activity extent was positively associated with the prevalence of DS use, with higher influence in males than females. In contrast, the only other similarly conducted study in young adults [39] did not reveal any effects of exercise level on the prevalence of DS use. Different conclusions of these two studies may be due to classification of participants into three physical activity-extent groups on the basis of different criteria (average DEEPA was used as a criterion for classification in the present study, and weekly frequency of vigorous exercise for duration of at least one hour in the study of Schulz [39]). In addition, the study of Schulz [39] was conducted on college student population, thus his participants were older (20.8 years old on average) than participants in our study (16.8 years old on average) conducted on secondary school population, which may also contribute to the observed differences. Finally, different conclusions of these studies may also be due to different sample size (N = 1463 in our study vs N = 333 in Schulz study [39]).

As much as 50 % of adolescents used two or more types of DS, which is far more than 18 % found in a study seven years earlier [8], but less than 76 % reported among elite athletes in roughly the same period [5]. There were significantly more multiple DS users among males than females, athletes than non-athletes, and among those with higher physical activity extent. The average number of DS consumed among DS users was 2–3, which is similar to data from other studies [4, 8, 15]. Interestingly, our results demonstrate that the average number of DS consumed was not associated with physical activity extent, which is in contrast to the conclusions of another study on males [27]. Different conclusions of these studies may be due to different sample size ($N = 1463$ in our study vs $N = 362$ in study of Herbold et al. [27]), or due to different types of DS studied.

The second part of this discussion will focus on some systematic comparisons of our and previous results on the prevalence of DS use, with a sincere intent of providing some lacking structure into the field. This is not an easy task, however, due to reasons presented above. Specifically, if we simultaneously consider gender, age and physical activity extent, a direct comparison of prevalence of DS use with those reported in previous studies, where these parameters were generally not considered, is rather difficult. Thus, in what follows, we only discuss those previous studies, to which our data about the prevalence of DS use among adolescents of both genders can be unequivocally compared.

The prevalence of adolescent athletes using DS at least several times per year was 76 % in our study, which is similar to the prevalence of 80 % of DS users reported among German elite athletes [4]. Nonetheless, our result is somewhat higher than 62 % reported among the athletes of United Kingdom [15] and much higher than 25 % among the Slovenian athletes [8] or USA athletes, for which prevalence of 38 % [21], 24 % [18] and 22 % [16] was reported. Furthermore, 62 % of athletes in our study using DS at least once per month is similar to 67 % of such users in the aforementioned German study [4], but another study [5] found a considerably higher prevalence of DS users among elite German athletes (91 %). In contrast, a USA study [21] demonstrated a considerably smaller prevalence of such users (32 %) among athletes. Comparison of athletes using DS at least once per week revealed the prevalence of 71 % [23] among the elite USA figure skaters, which was more than 51 % in our study. However, even lower values of 36 % and 27 % were reported among the Korean [19] and once more the USA [21] athlete adolescents, respectively. Finally, the value of 18 % of daily DS users in our study was substantially less than that of 51 % reported by Ziegler et al. [23] and 27 % reported by Diehl et al. [5], but comparable with 19 % reported by Sobal and Marquart [21].

When it comes to non-athletes adolescents, our study detected relatively high prevalence of DS use, although scientific evidence supports balanced nutrition as sufficient for health and sports participation [1]. For those using DS at least several times per year, the prevalence of 66 % observed in our study was lower than 74 % [27] and 71 % [28] reported among USA adolescents, but much higher than what other studies found among adolescents in USA, 34 % [14] and 46 % [31], as well as in Finland (45 %) [17] and Korea (27 %) [32]. Furthermore, it was dramatically higher than the prevalence of 16 % reported among Slovenian adolescents in a study performed just seven years earlier [8]. As it seems highly unlikely that the habits of DS use have changed this much in the same population in less than a decade, the main reason for this difference is most likely that, in that earlier study, the frequency of DS use was not considered. A large part of differences in the prevalence of DS use reported in different studies can thus likely be attributed to this same methodological issue. For adolescents using DS at least once per month, our study revealed the prevalence of 47 %, which is more than in several studies conducted in USA that revealed prevalence of 31 % [13], 29 % [31], 27 % [30], 27 % [26] and 26 % [24, 29], but less than in another USA study (58 %) [6]. For adolescents using DS at least once per week (35 % in our study), we were unable to find any other such study. For daily DS users, we found one comparable study of Stang et al. [14] reporting 16 % of such users, which was similar to our result of 13 %.

The results of this study demonstrate that MVMM (45 %), vitamins (45 %) and minerals (45 %) were the most frequently used DS among adolescents. This is in accordance with previous studies [6, 8, 29], however, the reported prevalences form a broad range from 17 % [8] to 91 % [5]. Results of the present study indicate a highly significant increase in the prevalence of DS use with increasing physical activity extent and for athlete adolescents, regardless of DS type and frequency of DS use. These findings can thus most likely explain a significant part of the large differences in the detected prevalence of DS use between the results of this and other studies, as various studies had focused on rather different subgroups.

The results of the present study demonstrate that DS use is positively associated with higher physical activity extent, which exerts higher influence in males than females. Previous studies performed on Slovenian adolescents demonstrated that athletes (members of sports-clubs) were, on average, twice as physically active as their peers [40] and their prevalence of DS use was significantly higher [8]. To our knowledge, no studies have yet examined the impact of physical activity extent on prevalence of DS use among adolescents similarly to our study; therefore, no further comparisons with other studies can yet be made on this topic.

This overview demonstrates that the reason for large differences in the previously reported prevalence of DS are primarily due to neglecting the frequency of DS use, but also from different study designs, particularly in the sample and study groups selection (e.g. in the definition of non-athletes vs athletes).

It is worthwhile commenting some methodological issues noted in review articles regarding the assessment of prevalence and frequency of DS use [7, 41]. Thus, according to McDowell [7], larger studies generally find a lower prevalence rate, but we did not notice any such relation when comparing our study to others. Furthermore, McDowell [7] noted that direct comparisons are impossible if different classifications of DS are used in questionnaires and proposed that studies should use a standardized list of the types of DS. In this regard, we fully agree, and suggest a development of a standardized questionnaire, using major categories of DS. Due to differing definitions of DS across countries this would, however, only be feasible if pursued through international organizations. As highlighted by Dickinson and MacKay [41], for an accurate estimate of the prevalence of DS use, the time period included in the questionnaire should not be shorter than one year, in order to capture both regular and occasional users. The results of the current study demonstrate that the frequency of DS use has an important impact on the detected prevalence of DS use and, consequently, the unequivocal specification of who is considered a DS user should be based on the frequency of DS use.

Some limitations and delimitations of our study should also be noted. First, the list of DS examined was not open-ended, thus users of other specific DS (e.g. herbal supplements) might have remained undetected. The other DS are, however, less frequently used according to Yussman et al. [42] and we believe that, although some underestimation in the prevalence of DS use in the whole population of adolescents might have occurred, all the major categories of DS were covered by our study. We therefore believe that our study managed to highlight, with scientific credibility, the methodological issues related to evaluation of the prevalence of DS use. Similarly to others, the present study might have also been subject to a recall bias, since the participants were requested to recall their DS use over the last year. Also, a more reliable approach for the assessment of physical activity extent would be the use of motion sensors or heart rate monitors, rather than a 7-day recall physical activity questionnaire. However, the SHAPES questionnaire was reported suitable for use in large-scale school-based data collections for adolescents [43]. We believe that the strength of our study lies in its highly systematic presentation of the errors in the assessment of prevalence of DS use. Our results clearly demonstrate that the frequency of DS use is a factor that has to be considered whenever DS use is being studied. Regardless of the population group and the associated variables in question, accounting for the frequency of DS use is indispensable to enable meaningful comparisons between future studies of DS use, as in previous studies this crucial parameter was largely ignored.

CONCLUSIONS

Our results clearly revealed that dietary supplementation is high not only in athlete adolescents, but also in non-athlete adolescents. Systematic analysis of the prevalence of DS use and its association with the extent of physical activity indicated that both a larger average DEEPA and sports-club membership are associated with larger prevalence of DS use among adolescents. A half of adolescents even used DS combinations. Furthermore, the present study clearly demonstrated the risk of making largely biased conclusions about DS use, if the frequency of DS use is not simultaneously considered. This fact has to be unconditionally taken into account to facilitate reliable comparison of studies.

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