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Table I. General characteristics of the study population

	Vocational ballet dancers (N= 152)		Children controls (N= 96)		Professional ballet dancers (N= 184)		Adult controls (N= 160)	
	Girls (N= 112)	Boys (N=40)	Girls (N= 56)	Boys (N= 40)	Female (N=129)	Male (N=55)	Female (N=110)	Male (N= 50)
	Age (yrs.) ⁽¹⁾	13.5 ± 2.4	13.2 ± 2.2	13.7 ± 2.2	13.3 ± 2.0	28.2 ± 9.5	27.3 ± 5.7	28.6 ± 9.4
Height (cm) ⁽¹⁾	155.8 ± 10.4	156.1 ± 15.5	155.3 ± 8.7	160.5 ± 10.3	158.0 ± 31.9	176.2 ± 4.3	162.6 ± 6.5	176.1 ± 5.7
Body mass (Kg) ⁽¹⁾	42.1 ± 8.7	44.3 ± 13.2	52.9 ± 12.3***	55.4 ± 13.1***	50.8 ± 5.2	70.0 ± 6.2	60.0 ± 10.1***	76.0 ± 11.6**
BMI (Kg/m ²) ⁽¹⁾	17.4 ± 5.7	17.8 ± 2.1	21.7 ± 3.8**	21.3 ± 3.9***	18.8 ± 22.7	22.5 ± 1.6	22.7 ± 3.7***	24.5 ± 3.5***
Lean mass (Kg) ⁽¹⁾	30.9 ± 6.5	34.3 ± 11.7	31.6 ± 4.9	36.5 ± 9.6	38.9 ± 3.8	57.8 ± 4.7	36.9 ± 5.3**	58.0 ± 10.0
Fat mass (Kg) ¹⁾	8.3 ± 17.3	6.7 ± 3.1	17.3 ± 6.1***	14.7 ± 7.2***	9.5 ± 19.8	10.8 ± 5.5	19.8 ± 8.0***	14.8 ± 7.7
Age menarche (yrs.) ⁽¹⁾	12.7 ± 2.2	-	11.1 ± 1.1***	-	14.3 ± 0.4	-	11.9 ± 1.3***	-
Gynaecological age (yrs.)	2.3 ± 1.8	-	3.4 ± 2.0**	-	13.9 ± 9.9	-	16.8 ± 10.6*	-
Primary amenorrhea ^(2,3)	4 (3.6%)	-	0 (0.0%)	-	30 (23.3%)	-	1 (0.9%)**	-
Smoking ⁽⁴⁾	-	-	-	-	29 (22.5%)	14 (25.5%)	19 (17.3%)	16 (32.0%)
Tanner staging ^(5,6)								
I	42 (37.5%)	12 (30.0%)	1 (1.7%)	0 (0.0%)	-	-	-	-
II	26 (23.2%)	18 (45.0%)	8 (14.3%)	9 (22.5%)	-	-	-	-
III	32 (28.6%)	3 (7.5%)	10 (17.9%)	14 (35.0%)	-	-	-	-
IV	10 (8.9%)	5 (12.5%)	23 (41.0%)	14 (35.0%)	-	-	-	-
V	2 (1.8%)	5 (12.5%)	5 (8.9%)	3 (7.5%)	-	-	-	-
Energy intake (Kcal/day)	1632.4 ± 492.1	1599.3 ± 463.9	1847.5 ± 477.2*	1877.3 ± 542.5*	-	-	-	-
Calcium intake (mg/day)	756.9 ± 375.1	725.3 ± 370.0	640.6 ± 327.9	652.2 ± 241.3	-	-	-	-
Vitamin D (mcg/day)	2.1 ± 2.4	1.8 ± 1.8	2.2 ± 1.6	2.1 ± 1.2	-	-	-	-
IGF-1 (ng/mL)	306.3 ± 115.8	241.7 ± 90.2	314.7 ± 114.1	287.0 ± 275.0	-	-	-	-
Physical exercise (h/week)	18.2 ± 7.0	19.5 ± 7.2	2.4 ± 0.5***	2.1 ± 0.4***	32.9 ± 8.4	32.5 ± 9.6	-	-
BMD FN (g/cm ²)	0.890 ± 0.015	0.893 ± 0.033	1.107 ± 0.022***	1.148 ± 0.030***	1.094 ± 0.018	1.224 ± 0.032	0.978 ± 0.016***	1.056 ± 0.021***
BMD LS (g/cm ²)	0.858 ± 0.017	0.821 ± 0.031	1.097 ± 0.024***	0.985 ± 0.028***	1.145 ± 0.016	1.207 ± 0.028	1.130 ± 0.014	1.094 ± 0.019**
BMD FA (g/cm ²)	0.591 ± 0.009	0.589 ± 0.016	0.769 ± 0.012***	0.729 ± 0.015***	0.670 ± 0.013	0.829 ± 0.020	0.763 ± 0.011***	0.804 ± 0.013

⁽¹⁾ Values are means ± SD

⁽²⁾ Value are percentages; indicate the percentage of dancers/controls with amenorrhea or oligomenorrhea by the time of the assessment (current menstrual status)

⁽³⁾ Value are percentages; indicate the percentage of dancers/controls with primary amenorrhea out of those that have reached the menarche by the time of the assessment

⁽⁴⁾ Values are percentages; indicate the percentage of professional ballet dancers/controls that reported smoking

⁽⁵⁾ Values are percentages; indicate the percentage of vocational ballet dancers/controls at each Tanner stage at the time of the assessment

⁽⁶⁾ Distribution of Tanner stages between female ($p < 0.001$) and male ($p < 0.001$) vocational ballet dancers and controls

Unadjusted BMD values for potential associated factors; BMD data were adjusted only for DXA-device and school/company

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; dancers (vocational or professional) significant different from controls

IGF-1 = insulin growth factor I; BMD = bone mineral density; FN = femoral neck; LS = lumbar spine; FA = forearm

Table II. Factors associated with BMD in vocational ballet dancers (children)

	Female				Male			
	Dancers	Controls	F	P	Dancers	Controls	F	P
BMD Femoral neck⁽¹⁾								
Dancer vs. Control	0.591 ± 0.009	0.768 ± 0.012***	129.863	0.000	0.589 ± 0.016	0.729 ± 0.015***	39.095	0.000
Body mass	0.943 ± 0.013	1.034 ± 0.024**	97.566	0.000	0.968 ± 0.025	1.077 ± 0.026**	56.224	0.000
Lean mass	0.593 ± 0.008	0.770 ± 0.011***	68.840	0.000	0.590 ± 0.011	0.727 ± 0.010***	94.281	0.000
Fat mass	0.613 ± 0.010	0.730 ± 0.016***	12.334	0.001	0.588 ± 0.018	0.729 ± 0.017***	0.005	0.946
Tanner stage	0.956 ± 0.013	0.968 ± 0.026	107.406	0.000	0.987 ± 0.025	1.073 ± 0.025*	70.829	0.000
Age at menarche	0.991 ± 0.026	1.151 ± 0.031***	1.379	0.243	-	-	-	-
Gynaecological age	1.025 ± 0.023	1.098 ± 0.028	14.879	0.000	-	-	-	-
Energy intake	0.897 ± 0.015	1.179 ± 0.052***	6.144	0.014	0.901 ± 0.032	1.084 ± 0.032***	5.524	0.022
BMD Lumbar spine⁽¹⁾								
Dancer vs. Control	0.858 ± 0.017	1.097 ± 0.024***	65.568	0.000	0.821 ± 0.031	0.985 ± 0.028***	15.120	0.000
Body mass	0.917 ± 0.013	1.016 ± 0.025**	136.834	0.000	0.890 ± 0.021	0.907 ± 0.021	107.557	0.000
Lean mass	0.866 ± 0.014	1.095 ± 0.020***	91.746	0.000	0.824 ± 0.019	0.978 ± 0.017***	145.894	0.000
Fat mass	0.902 ± 0.019	1.023 ± 0.030**	11.139	0.001	0.828 ± 0.035	0.975 ± 0.032**	0.220	0.640
Tanner stage	0.927 ± 0.014	0.954 ± 0.028	117.896	0.000	0.906 ± 0.022	0.900 ± 0.021	100.105	0.000
Age at menarche	0.972 ± 0.027	1.159 ± 0.032***	0.514	0.476	-	-	-	-
Gynaecological age	1.007 ± 0.024	1.103 ± 0.029*	19.896	0.000	-	-	-	-
Energy intake	0.866 ± 0.017	1.074 ± 0.060**	1.317	0.253	0.823 ± 0.030	0.911 ± 0.031*	6.591	0.013
BMD Forearm⁽¹⁾								
Dancer vs. Control	0.591 ± 0.009	0.768 ± 0.012***	129.863	0.000	0.589 ± 0.016	0.729 ± 0.016***	39.095	0.000
Body mass	0.617 ± 0.007	0.739 ± 0.014***	86.416	0.000	0.617 ± 0.012	0.692 ± 0.013***	68.208	0.000
Lean mass	0.593 ± 0.008	0.770 ± 0.011***	69.840	0.000	0.590 ± 0.011	0.727 ± 0.010***	94.281	0.000
Fat mass	0.613 ± 0.010	0.730 ± 0.016***	12.334	0.001	0.588 ± 0.018	0.729 ± 0.017***	0.005	0.946
Tanner stage	0.632 ± 0.070	0.690 ± 0.014***	137.451	0.000	0.613 ± 0.011	0.686 ± 0.011**	113.363	0.000
Age at menarche	0.644 ± 0.015	0.802 ± 0.017***	0.003	0.960	-	-	-	-
Gynaecological age	0.656 ± 0.014	0.782 ± 0.016***	11.336	0.001	-	-	-	-
Energy intake	0.597 ± 0.009	0.781 ± 0.030***	1.272	0.262	0.582 ± 0.017	0.692 ± 0.017***	4.560	0.037

Values are means ± SD

Adjusted BMD values for potential associated factors; BMD data were adjusted also for DXA-device and school/company

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; dancers (vocational or professional) significant different from controls

BMD = bone mineral density

Table III. Factors associated with BMD in professional ballet dancers (adults)

	Female				Male			
	Dancers	Controls	F	P	Dancers	Controls	F	P
BMD Femoral neck⁽¹⁾								
Dancer vs. Control	1.094 ± 0.018	0.978 ± 0.016***	22.067	0.000	1.224 ± 0.032	1.056 ± 0.021***	19.556	0.000
Body mass	1.099 ± 0.033	0.977 ± 0.016**	3.325	0.070	1.224 ± 0.033	1.056 ± 0.021***	0.000	0.990
Lean mass	1.093 ± 0.019	0.918 ± 0.016***	4.179	0.042	1.272 ± 0.038	1.053 ± 0.021***	0.789	0.378
Fat mass	1.111 ± 0.021	0.967 ± 0.018***	0.931	0.336	1.261 ± 0.039	1.057 ± 0.021***	1.587	0.213
Age at menarche	1.096 ± 0.035	0.981 ± 0.017	0.511	0.476	-	-	-	-
Gynaecological age	1.088 ± 0.032	0.987 ± 0.015**	18.386	0.000	-	-	-	-
BMD Lumbar spine⁽¹⁾								
Dancer vs. Control	1.145 ± 0.016	1.113 ± 0.014	2.106	0.148	1.207 ± 0.028	1.094 ± 0.019**	10.845	0.002
Body mass	1.122 ± 0.029	1.096 ± 0.014	11.904	0.001	1.224 ± 0.028	1.086 ± 0.019	7.472	0.008
Lean mass	1.153 ± 0.017	1.117 ± 0.014	2.719	0.101	1.240 ± 0.032	1.098 ± 0.019***	8.128	0.006
Fat mass	1.194 ± 0.019	1.090 ± 0.015***	12.370	0.001	1.260 ± 0.037	1.099 ± 0.020***	0.172	0.679
Age at menarche	1.123 ± 0.030	1.103 ± 0.014	5.547	0.018	-	-	-	-
Gynaecological age	1.102 ± 0.029	1.116 ± 0.013	6.186	0.014	-	-	-	-
BMD Forearm⁽¹⁾								
Dancer vs. Control	0.670 ± 0.013	0.763 ± 0.011***	27.337	0.000	0.829 ± 0.020	0.804 ± 0.013	1.228	0.272
Body mass	0.587 ± 0.024	0.754 ± 0.012**	1.370	0.243	0.837 ± 0.020	0.800 ± 0.013	3.739	0.057
Lean mass	0.671 ± 0.014	0.766 ± 0.012***	0.535	0.465	0.848 ± 0.025	0.806 ± 0.014	0.243	0.624
Fat mass	0.685 ± 0.015	0.755 ± 0.013**	4.990	0.027	0.858 ± 0.024	0.803 ± 0.013	4.553	0.037
Age at menarche	0.708 ± 0.024	0.742 ± 0.012	14.861	0.000	-	-	-	-
Gynaecological age	0.683 ± 0.022	0.758 ± 0.010**	24.885	0.000	-	-	-	-

Values are means ± SD

Adjusted BMD values for potential associated factors; BMD data were adjusted also for DXA-device and school/company

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; dancers (vocational or professional) significant different from controls

BMD = bone mineral density

Table IV. Prevalence of low bone mineral density in vocational dancers and aged- and sex-matched controls

	ISCD criteria					
	LS (%)		FN (%)		FA (%)	
	Female	Male	Female	Male	Female	Male
Vocational dancers	16.4	7.5	8.3	10.5	9.2	2.5
Controls	5.5*	2.1	12.7	4.2	0.0**	2.2

Values are percentages

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; dancers significant different from controls (Chi-square test)

LS = lumbar spine; FN = femoral neck; FA = forearm

The International Society of Clinical Densitometry (ISCD) criterion was used to assess vocational dancers and aged- and sex-matched controls: “low BMD” was defined for a Z-score less than -2.0