Bone Density Following Long Duration Space Flight and Recovery

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BACKGROUND

- Space flight is associated with a loss of load-bearing activity on the human skeleton due to the effects of microgravity ("weightlessness").
- During space flight, bone mineral density [BMD] at load-bearing sites of the hip and spine in particular sustain losses of an estimated 0.5-1.0% per month (LeBlanc et al, XXXX)
- There is evidence that BMD can increase following return from long-duration space flight but the estimated rate of recovery is much slower compared with the rate of loss sustained and there is considerable variability in recovery observed between individual crew members (Sibonga et al, Bone 200X)
- Most BMD data following long-duration space flight have been from male crew members, not women, and it is unknown if BMD rates of loss or recovery are similar for men and women.
- It is also unknown whether the variability in rates of BMD recovery reflect changes in BMD that may naturally be expected to occur with aging.

OBJECTIVES

- To create prediction models for BMD change using a community-based sample of adults which include men and women in the age range of US crew serving on long-duration space flights.
- To compare the observed BMD change of US crew following long-duration space flights with what would be predicted if they had not experienced microgravity.

METHODS

Study Subjects

- All US crew members serving on long-duration space flight missions. [N=32, 26 men (age range: 37-54 yrs) and 6 women (age: 41-53 yrs)]
- Prediction models were created from 348 men (age: 22-90 yrs) and 351 women (age: 21-93 yrs) representing an age- and sex-stratified random sample of the Rochester, MN community.

METHODS

BMD Measurements in US Crew members

- BMD (g/cm^2) was measured in US crew members pre-flight, immediately post-flight and ~12 months post-flight
- BMD from US crew members were measured using DXA (Hologic QDR 2000, QDR 45000 and Discovery scanners), with the majority having pre- and post-flight measurements on the same machine.
- BMD measures at the total hip, lumbar spine, wrist (ultradistal and mid-shadt radius) and total body were used in analyses.

BMD Measurements in Community-Based Cohort

- BMD (g/cm^2) was measured in the community-based cohort at baseline, 1 yr, 2 yrs and 4 yrs of follow-up in women and baseline, 2 yrs and 4 yrs of follow-up in men using the QDR 2000 scanner and at the same sites listed for US crew members.

Analyses

- We created prediction models for follow-up BMD for men and women separately.
- We used linear mixed-effects models to predict follow-up BMD using baseline BMD, age and follow-up time, adjusting for the fact that most people were measured more than once.
- We then applied the created models to predict follow-up BMD for US crew members and compared them to what was actually observed immediately post-flight and at ~ 12 months post-flight

RESULTS

- Median flight duration was 161 days (range 58-199 days) for the 26 men and 176 days (range 91-195) for the 6 women.
- 32/32 had a pre-flight as well as immediate post-flight BMD measured at the hip or spine a median of 6 days (range: 3-56 days) post-landing
- 28/32 had BMD measurements a median of 12 months post landing (range 6-18 months).

RESULTS

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(Men Imm Post Flight)

RESULTS

(Tables)

Women Imm Post Flight

RESULTS

(Tables)

Men 12 mos Post Flight)

RESULTS

(Tables)

Women 12 mos Post Flight

SUMMARY

- Men had lower BMD at all sites immediately post-flight and for most sites following 12 months since return than would be predicted.
- Women appeared to have a lower rate of loss than men at load-bearing sites of the hip and spine, and had smaller differences in the observed vs. predicted values than men, but the N is small and confidence limits wide.

LIMITATIONS

- BMD is a surrogate predictor of bone strength and differences in observed and predicted BMD may still underestimate the changes in bone strength given recent data based on finite-element models from QCT scans of some US crew (Lang/Keyak).
- The N for women is too small to make definitive conclusions.

CONCLUSIONS

- At ~12 months, BMD at most sites in men remained lower than would be predicted, raising concerns for long-term bone health consequences following space flight. Additional analyses based on longer follow-up are being conducted.
- Although the N is too small for definitive conclusions, women had lower rates of loss at load-bearing sites of the hip and spine immediately post-flight relative to men and smaller differences between observed vs. predicted BMD at most sites, both immediately and 12 months post-flight, relative to men. The role of other exposures/risk factors need to be explored to further understand these possible gender differences in BMD loss and recovery following long-duration space flight.

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ALL N=32

BMD Site	Mean Immediate Post-Flight BMD (g/cm^2) % Change per Month (% chg/mos)				
	Expected		Observed		
	BMD	% chg/mos (95% CI)	BMD	% chg/mos (95% CI)	p-value
Total Hip	1.069	-0.02 (-0.06, 0.02)	1.008	-0.76 (-0.91, -0.61)	<0.001
Lumbar Spine	1.087	0.11 (0.10, 0.13)	1.040	-0.41 (-0.56, -0.26)	<0.001
Ultradistal Radius*	0.526	-0.02 (-0.04, 0.00)	0.506	-0.21 (-0.31, -0.11)	<0.001
Mid Shaft Radius*	0.708	0.16 (0.10, 0.21)	0.695	-0.05 (-0.13, 0.02)	<0.001
Total Body	1.255	-0.05 (-0.05,-0.04)	1.236	-0.21 (-0.31, -0.12)	0.002

**radius sites are based on 24 crewmembers*

MEN N=26

BMD Site	Mean Immediate Post-Flight BMD (g/cm^2) % Change per Month (% chg/mos)				
	Expected		Observed		
	BMD	% chg/mos (95% CI)	BMD	% chg/mos (95% CI)	p-value
Total Hip	1.096	0.03 (0.01, 0.06)	1.024	-0.83 (-1.01, -0.65)	<0.001
Lumbar Spine	1.094	0.12 (0.11, 0.14)	1.040	-0.48 (-0.65, -0.31)	<0.001
Ultradistal Radius*	0.539	-0.04 (-0.05, -0.03)	0.531	-0.21 (-0.33, -0.10)	<0.01
Mid Shaft Radius*	0.741	0.20 (0.15, 0.25)	0.722	-0.02 (-0.10, -0.06)	<0.001
Total Body	1.286	-0.05 (-0.06,-0.04)	1.267	-0.21 (-0.31, -0.10)	<0.01

**radius sites are based on 19 men*

WOMEN N=6

BMD Site	Mean Immediate Post-Flight BMD (g/cm^2) % Change per Month (% chg/mos)				
	Expected		Observed		
	BMD	% chg/mos (95% CI)	BMD	% chg/mos (95% CI)	p-value
Total Hip	0.952	-0.23 (-0.30, -0.17)	0.935	-0.46 (-0.68, -0.24)	0.07
Lumbar Spine	1.059	0.06 (0.02, 0.10)	1.041	-0.15 (-0.44, 0.14)	0.12
Ultradistal Radius*	0.422	0.07 (0.03, 0.12)	0.413	-0.20 (-0.44, 0.04)	0.03
Mid Shaft Radius*	0.606	0.00 (-0.01, 0.02)	0.597	-0.16 (-0.37, 0.04)	0.15
Total Body	1.112	-0.05 (-0.06,-0.04)	1.100	-0.21 (-0.31, -0.12)	0.10

**radius sites are based on 5 crewmembers*

ALL N=28

BMD Site*	Mean ~1 Year Post-Flight BMD (g/cm^2) % Change per Month (% chg/mos)				
	Expected		Observed		
	BMD	% chg/mos (95% CI)	BMD	% chg/mos (95% CI)	p-value
Total Hip	1.086	0.01 (-0.01, 0.02)	1.061	-0.11 (-0.15, -0.07)	<0.001
Lumbar Spine	1.093	0.05 (0.05, 0.06)	1.081	-0.00 (-0.06, 0.05)	0.03
Ultradistal Radius*	0.520	-0.07 (-0.07,-0.06)	0.526	-0.01 (-0.05, 0.02)	0.001
Mid Shaft Radius*	0.712	0.06 (0.04, 0.08)	0.701	-0.01 (-0.05, 0.03)	0.004
Total Body	1.265	-0.02 (-0.03,-0.02)	1.250	-0.08 (-0.14, -0.02)	0.05

**radius sites are based on 20 crewmembers*

MEN N=24

BMD Site*	Mean ~1 Year Post-Flight BMD (g/cm^2) % Change per Month (% chg/mos)				
	Expected		Observed		
	BMD	% chg/mos (95% CI)	BMD	% chg/mos (95% CI)	p-value
Total Hip	1.100	0.02 (0.01, 0.03)	1.072	-0.11 (-0.16, -0.07)	<0.001
Lumbar Spine	1.092	0.05 (0.05, 0.06)	1.078	-0.01 (-0.07, 0.05)	0.02
Ultradistal Radius*	0.539	-0.07 (-0.07, 0.06)	0.546	-0.01 (-0.05, 0.02)	<0.01
Mid Shaft Radius*	0.733	0.07 (0.05, 0.09)	0.721	-0.01 (-0.05, 0.03)	<0.01
Total Body	1.286	-0.02 (-0.03,-0.02)	1.269	-0.08 (-0.14,-0.01)	0.07

**radius sites are based on 17 crewmembers*

WOMEN N=4

BMD Site*	Mean ~1 Year Post-Flight BMD (g/cm^2) % Change per Month (% chg/mos)				
	Expected		Observed		
	BMD	% chg/mos (95% CI)	BMD	% chg/mos (95% CI)	p-value
Total Hip	0.999	-0.05 (-0.08, -0.03)	0.995	-0.07 (-0.13, -0.01)	0.55
Lumbar Spine	1.098	0.04 (0.02, 0.06)	1.098	0.04 (-0.16, 0.25)	0.99
Ultradistal Radius*	0.411	-0.06 (-0.09,-0.04)	0.416	-0.01 (-0.32, 0.29)	0.54
Mid Shaft Radius*	0.589	-0.01 (-0.02, -0.00)	0.588	-0.01 (-0.24, 0.22)	0.92
Total Body	1.142	-0.03 (-0.04,-0.02)	1.132	-0.08 (-0.27, 0.12)	0.53

**radius sites are based on 3 crewmembers*