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ORIGINAL ARTICLE

The moderating impact of lifestyle factors on sex steroids, sexual activities and aging in Asian men

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The present study sought to evaluate the relative associations of exercise, sleep and other lifestyle habits with aging, sex hormones, percent body fat (%BF) and sexual activities in men living in the community. A better understanding of this complex interrelationship is important in helping the formulation of modalities for a holistic approach to the management of aging men. The results showed that age is a major determinant for many physiological parameters, including sleep, hormonal and metabolic parameters, some lifestyle factors and sexual activities. Testosterone (T), bioavailable testosterone (BioT) and dehydroepiandrosterone sulphate (DHEAS) concentrations decreased with age, while estradiol (E2), sex hormone-binding globulin (SHBG) and %BF increased with age. In addition, there exist intricate associations among hormonal and lifestyle factors, %BF and age. High-intensity exercise and longer duration of sleep were associated with higher concentrations of T and BioT. T was shown to be associated positively with men who were engaged in masturbation. DHEAS was associated with men wanting more sex and with good morning penile rigidity. Older Singaporean men tended to sleep for shorter duration, but exercised more intensely than younger men. Coital and masturbation frequencies decreased with age, and a significantly greater number of younger men were engaged in masturbation. Relationship between the partners is a key determinant of sexuality in men. It appears that T may have a limited, while dehydroepiandrosterone (DHEA) have a greater role than previously suggest, as a motivational signal for sexual function in men. Both biological and psychosocial factors interact with each other to influence sexual functions in men. Hence, a biopsychosocial approach may be more appropriate for a more lasting resolution to sexual dysfunctions in men.
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INTRODUCTION

After decades of trailing behind women, understanding of how aging affects men's health has grown rapidly over the last 15 years. There is increasing evidence that aging is associated with changes in almost every health compartment, ranging from cardiovascular, metabolic, sexual and cognitive health.[1–4]

Changes in hormone concentrations, especially those of androgens, were noted in men.[5–7] Age-related decline in androgen concentrations associated with a variety of pathological conditions including decreased sexual functions, loss of muscle mass, increased risk of osteoporosis, decline in cognitive functions, increased percent body fat (%BF) and insulin resistance, changes in other metabolic and cardiovascular risk factors, and poor quality of life has been termed late-onset hypogonadism.[5,8–14]

While the physiological roles of testosterone (T) and its metabolites were well established, those of estrogens and dehydroepiandrosterone (DHEA) in men were less well defined. Recent studies have attributed some possible roles, albeit still equivocal, for estrogens in sexual, behavioral, bone, cardiovascular and other metabolic functions in men[14,15] and for DHEA, in bone metabolism, body composition and cognition.[16,17]

Besides age, some lifestyle factors were variably correlated to androgens, metabolic factors, and sexual functions.[5,18–22] Regular physical exercise is an important lifestyle factor that could enhance or maintain physical fitness and provide many health benefits other than weight management. Frequent and regular physical exercise can boost the immune system, and help prevent illnesses such as heart and cardiovascular diseases, type 2 diabetes and obesity,[23,24] improve the range of motion of muscles and joints and muscle strength,[25,26] and improve some hormone productions.[27] The impact of sleep on health, on the other hand, has been less well researched.

Research over the last 15 years clearly shows that aging affect many health compartments in an integrated manner.[5] In the light of the integrated manner of action, the present study sought to evaluate the relative associations of exercise, sleep and other lifestyle habits with aging, hormone concentrations, metabolic factors and sexual activities in men living in the community. A better understanding of this complex interrelationship is important in helping the formulation of modalities for a holistic approach to the management of aging men.

MATERIALS AND METHODS

Institutional approval for the study was obtained and each volunteer gave his written informed consent. Ethnic differences existed and, therefore, only 531 Singaporean Chinese men aged between 29 and 72 years were included in this analysis. Subjects were recruited from the general public through an open invitation, first through an

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announcement during the World Congress in Sexology held in Singapore. The announcement was included in the major newspapers in Singapore. Continual recruitment was assisted through word of mouth from volunteer to volunteer. The targeted number of men between the ages of 30 to 70 years was 400. As the primary objective was to evaluate the determinants of the aging process, subjects who have or have had, and were treated for major illnesses were excluded from the study. Only subjects with no known existing or history of major medical illnesses, such as cancer, hypertension, thyroid dysfunction, diabetes, osteoporotic fracture and cardiovascular events, were included in the present study. Subjects were not paid for participation. Singapore is a highly urbanized city state with no rural population. Subjects involved in this study represent the diverse spectra of the population in Singapore, and include those with low and high levels of education, working and non-working men (retirees), and men with various vocations. The methods have been reported earlier.[5,28,29]

Each subject answered a self-administered and investigator-guided questionnaire. Questions asked covered their medical, dietary, social, sex and family histories, and other histories regarding consumption of hormones, supplements and medication, types of beverages, smoking and alcohol consumption.

The self-administered, investigator-guided questionnaire has not been validated, but contained questions that could be categorized. In this questionnaire, subjects were asked to score their average sleep duration per night as well as some common sexual activities listed below over the last 6 months.

Sleep parameters

a. Sleep duration per night (SlpD)	Score
• <4 h	1
• ⩾4–6 h	2
• ⩾6–8 h	3
• >8 h	4
b. Do you have a problem falling asleep (Fallaslp)	
• No	1
• Yes	2

Sexual activities

a. How many times do you have coitus each month? (CoitalF) _____/month

b. Are you satisfied with your coital frequency? (Desire)	
• No, I want more sex	1
• Yes, I am happy with my coital frequency	2
• No, I want less frequent sex	3
c. Do you masturbate? (Masturbate)	
• No	1
• Yes	2

d. If yes, how many times per month? (No.Times) _____/month

e. What is the penile rigidity of your morning erection (Rigid)?	
• Poor	1
• Average	2
• Good	3

Smoking and alcohol consumption

a. Do you smoke? (Smoke)	
• No	1
• Yes, with less than 10 sticks/day	2
• Yes, more than 10 sticks/day	3
b. Do you consume alcohol (beer, wine, liquor)? (Drink)	
• No	1
• Yes, a drink 2–3 times/week	2
• Yes, a drink everyday	3

Relationship with partner (Rel)

How is your relationship with your partner?	
• Average	1
• Good	2
• Very Good	3

Exercise scores (metabolic equivalent-min (MET-min))

Unlike in our earlier studies[5,30] when physical exercise scores were based on type and frequency only, exercise scoring in the present study was based on metabolic equivalents (MET) and took into account the type, frequency and duration of each exercise episode. In accordance to the guidelines for Americans,[31] the MET cutoff values were as follow: light intensity (<3 MET), moderate intensity (3–6 MET) and high intensity (>6 MET). The exercise score per week was expressed as metabolic equivalent-min (MET-min). From the input in the self-administered questionnaire, each exercise type was given an exercise score. For example, running and brisk walking were given MET of 10 and 4.5, respectively. An individual who ran three times a week and each time for 30 min will have a total score of $10\times3\times30=900$ MET-min. While a person who brisk walked for 30 min and six times per week will have a total score of $4.5\times30\times6=810$ MET-min. Those who did not exercise routinely were given an arbitrary score of zero MET-min. The exercise intensities were categorized into four MET groups: METGp1 (no exercise, MET-min=0), METGp2 (low intensity, MET-min<500), METGp3 (moderate intensity, MET-min=500–1000) and METGp4 (high intensity, MET-min>1000).

Hormonal assays for T, estradiol (E2), sex hormone-binding globulin (SHBG) and dehydroepiandrosterone sulphate (DHEAS)

Serum total T and E2 concentrations were measured using reagents and methods recommended by the World Health Organization Matched Reagent Program[32] with modifications into the scintillation proximity methods established in-house.[33] SHBG and DHEAS were measured using methods reported earlier.[34] The intra- and inter-assay coefficients of variation were less than 15% over the effective concentration ranges for T, E2, SHBG and DHEAS.

Method of calculation of bioavailable testosterone (BioT)

BioT was calculated using the computer formula of Vermeulen which is available on the ISSAM website. Total T was computed as ng dl^{-1} while that for SHBG as nmol l^{-1}. Albumin level was assumed to be 44. Hence, BioT was expressed ng dl^{-1}.[35]

%BF

Every man had a whole body fat scan using the DEXA (Hologic, Bedford, MA, USA);[5] therefore, the body fat based on the Siri formula used by the DEXA machine was used as the index for total %BF. This is preferred over the conventional use of BMI as an index of total body fat as shown in an earlier publication.[36]

Statistical analysis

Statistical analyses were performed using SPSS for windows version 17.0 (SPSS Inc., Chicago, IL, USA). Basic descriptive statistics, as well as comparison of means using one-way ANOVA and the univariate analyses of the general linear model coupled with the least significant difference as the *post hoc* test for multiple means, were used on continuous measurements and where appropriate. For the non-continuous measurements such as number of men who

masturbated, sleep duration and desire for sex, the chi-squared analyses were used.

Age is a major determinant, and many of the parameters interact with each other and with age. Therefore, multiple regression analyses and the general linear model univariate regression analyses of variance for one dependent variable were done with the relevant parameters as covariates (stated below the tables of results). The alpha was set at 0.05.

RESULTS

Multiple regression analyses of various parameters with age

Using multiple regression analyses, age was significantly and independently correlated with several sex hormones, %BF, exercise scores (MET-min) and CoitalF (**Table 1**). The results in this table were slightly different from the earlier report[28] because of the inclusion of smoking, drinking and MET-min as covariates in the analyses. In general, men who drink are light drinkers. Even those who drink regularly do not indulged in heavy drinking. Young drinkers tend to drink more frequently than older men (**Table 1**). Changes were most noticeable for T which, contrary to the earlier report, showed significant decreases with age, a decrease of 17.2% in men above 60 years as compared to men below 40 years (**Table 2**). As reported earlier,[28] DHEAS was lower by 40.4%, BioT by 21.0%, and SHBG was higher by 22.6% and E2 by 19.2% in men above 60 years when compared to men below 40 years (**Table 2**). Men above 60 years had, on an average, 1.6% more body fat than men below 40 years (**Table 2**).

Table 1 Multiple regression of age with other parameters

Age with parameters	*Alpha*	P *values*
T (ng dl^{-1})	−0.168[a]	0.003
SHBG (nmol l^{-1})	0.249	0.000
BioT (ng dl^{-1})	−0.165	0.001
DHEAS (ng ml^{-1})	−0.325	0.000
E2 (pg ml^{-1})	0.114	0.010
%BF	0.133	0.003
MET-min	0.141	0.000
CoitalF (times per month)	−0.376	0.000
Difficulty of falling asleep	0.227	0.037
Regularity of alcohol consumption	−0.106	0.022

Abbreviations: %BF, percent body fat; BioT, bioavailable testosterone; CoitalF, coital frequency; DHEAS, dehydroepiandrosterone sulphate; E2, estradiol; MET-min, metabolic equivalent-min; SHBG, sex hormone-binding globulin; T, testosterone.
[a] T showed a negative correlation with age when all these covariates were included.

CoitalF and the number of times that men engaged in masturbation were reduced by 58.3% and 73.2%, respectively, in men above 60 years when compared with men less than 40 years (**Table 2**). Similarly, significantly fewer men engaged in masturbation in the older compared with the younger age groups (**Table 2**). In addition, fewer older than younger men had good penile rigidity in their morning erection (**Table 2**).

There were significantly more men older than 50 years who slept less as compared with younger men (<40 years). More than 22% of men older than 50 years routinely slept less than 6 h nightly, as compared with 8.3% of men younger than 40 years (**Table 2**).

Interrelationships among hormones, metabolic and lifestyle factors

The well-established interrelationships among total T, BioT, SHBG and E2 were noted in our study (**Table 3**). Smoking was associated with higher T levels but lower total body fat. The more regular the alcohol consumption, the lower the SHBG and insulin-like growth factor 1 (IGF1) levels. Those men who drink regularly were significantly associated with higher MET-min. MET-min was positively and negatively associated with SHBG and %BF, respectively.

Correlations between exercise groups and various parameters

Table 4 showed that changes in many parameters were associated with the different levels of intensity of physical exercise. Interestingly, men who exercise more intensely were significantly older than those in the lower exercise intensity groups. Both T and BioT concentrations in the moderate- and high-intensity groups (METGp3 and METGp4) were significantly higher than those in the low intensity group (T: 15% and 16%; BioT: 11%–20%, respectively). SHBG levels in the moderate- and high-intensity groups were 9.0%–16.2% higher than those who did not or exercise with low intensity (METGp1 and METGp2). %BF was the lowest in the high-intensity groups as compared to those in the

Table 2 Comparisons of various parameters among the different age groups. Values denote mean±s.e.

Parameter	*AgeGp1 (<40 years)* (n=*49*)	*AgeGp2 (40–49years)* (n=*173*)	*AgeGp3 (50–59 years)* (n=*157*)	*AgeGp4 (⩾60 years)* (n=*62*)
Age (year)	37.8±0.4[a]	46.1±0.2[b]	54.6±0.2[c]	63.0±0.8
T (ng dl^{-1})	574.9±24.6[b]	529.1±12.9[b]	483.3±13.6	475.8±22.3
BioT (ng dl^{-1})	315±16[b]	286±8[b]	253±9	249±14
SHBG (nmol l^{-1})	26.5±1.4[b]	28.1±0.7[b]	32.2±0.8	32.5±1.3
E2 (pg ml^{-1})	28.6±1.9[a]	33.2±1.0	35.8±1.1	34.1±1.7
DHEAS (ng ml^{-1})	2979±153[b]	2672±80[b]	2216±85	1774±135
%BF	16.8±0.6[b]	17.6±0.3	18.4±0.3	18.4±0.5
MET-min	506±118	588±61	636±65	1018±104[d]
CoitalF (times per month)	5.13±0.48[b]	4.87±0.23[b]	3.89±0.25[c]	2.14±0.44
Masturbation time per month	5.29±0.59[a]	2.81±0.33	2.50±0.44	1.42±0.70
% who masturbated	51.8[e]	34.6[f]	23.3	32.8
% who sleep >6 h	91.7[g]	87.6[g]	78.0	73.1
Good penile rigidity (%)	64.3	65.2	61.5	37.5[h]

Abbreviations: %BF, percent body fat; BioT, bioavailable testosterone; CoitalF, coital frequency; DHEAS, dehydroepiandrosterone sulphate; E2, estradiol; MET-min, metabolic equivalent-min; SHBG, sex hormone-binding globulin; T, testosterone.
[a,b,d] $P<0.05$, versus the other three groups.
[c] $P<0.05$, versus AgeGp4.
[e,h] $P<0.05$, versus the other three groups, chi-square test.
[f] $P<0.05$, versus AgeGp3, chi-square test.
[g] $P<0.05$, versus AgeGp4, chi-square test.

Table 3 Multiple regression of sex hormones and other parameters

	Alpha	P *values*
T with parameters		
SHBG (nmol l^{-1})	0.345	0.000
E2 (pg ml^{-1})	0.235	0.000
Heaviness of smoking	0.095	0.040
BioT with parameters		
E2 (pg ml^{-1})	0.234	0.000
Regularity of drink (alcohol)	0.100	0.034
SHBG with parameters		
T (ng dl^{-1})	0.344	0.000
MET-min	0.091	0.041
Regularity of drink (alcohol)	−0.114	0.013
E2 with parameters		
T (ng dl^{-1})	0.271	0.000
IGF1 (ng ml^{-1})	0.123	0.013
IGF1 with parameters		
IGFBP3 (ng ml^{-1})	0.302	0.000
E2 (pg ml^{-1})	0.114	0.013
Regularity of drink (alcohol)	−0.124	0.008
MET-min with parameters		
SHBG (nmol l^{-1})	0.105	0.041
%BF	−0.198	0.000
Regularity of drink (alcohol)	0.133	0.003
%BF with parameters		
T (ng dl^{-1})	−0.145	0.001
MET-min	−0.210	0.000
Heaviness of smoking	−0.129	0.005

Abbreviations: %BF, percent body fat; E2, estradiol; IGF1, insulin-like growth factor 1; IGFBP3, insulin-like growth factor-binding protein 3; MET-min, metabolic equivalent-min; SHBG, sex hormone-binding globulin; T, testosterone.

moderate to non-exercise groups, by 2.21% when comparing the high to the non-exercise groups.

Some sexual functions were associated with the intensity of exercise. Significantly more men who exercised with high intensity were engaged in masturbation than those who did not exercise at all. Significantly more men who exercised moderately intense were happy with their CoitalF than men in the other three exercise groups (**Table 4**). Significantly more men who did not exercise at all had difficulty falling asleep than those who exercised intensely (**Table 4**).

Correlations between sleep duration groups and various parameters

According to **Table 5**, significantly more men older than 60 years compared to younger men (<40 years) sleep less than 6 h. Longer sleep duration was associated with higher T and BioT. Total T and BioT in men who slept 6–8 h were higher than those who slept 4–6 h and <4 h, respectively (T: 9.8% and 39.0%; BioT: 7.0% and 29.0%).

Correlations between drinking and other parameters

According to **Table 6**, men who drink alcohol regularly had significantly higher BioT levels, but lower SHBG, IGF1 and insulin-like growth factor-binding protein 3 (IGFBP3) levels than those men who did not drink. Heavy smokers had significantly higher T and BioT levels than men who did not smoke at all.

Differences of various parameters in men who did not and those who did masturbate

Table 7 shows men who engaged in masturbation were significantly younger, had higher T and BioT concentrations than those who did

Table 4 Various parameters by exercise intensity groups (METGp). The values denote the mean±s.e.

Parameter	*METGp1 (0)* (n=*155*)	*METGp2 (<500)* (n=*155*)	*METGp3 (500–1000)* (n=*103*)	*METGp4 (>1000)* (n=*118*)
Age (year)	49.25±0.70	49.78±0.70	50.52±0.86	53.05±0.80[a]
T (ng dl^{-1})	505.4±16.2	475.5±14.8[b]	551.8±18.2	546.8±17.1
BioT (ng dl^{-1})	273±9	251±9[b]	301±11	279±10
SHBG (nmol l^{-1})	28.9±0.9[c]	27.7±0.8[b]	31.5±1.0	32.2±1.0
%BF	18.69±0.42[d]	17.89±0.38	17.95±0.47	16.48±0.44
Problem of falling asleep (%)	10.3[e]	3.4	2.4	2.2
Masturbate (%)	26.6[e]	30.0	33.0	41.6
% happy with CoitalF	63.1	62.5	84.4[f]	66.3

Abbreviations: %BF, percent body fat; BioT, bioavailable testosterone; CoitalF, coital frequency; SHBG, sex hormone-binding globulin; T, testosterone.
[a,d] $P<0.05$, versus the other three groups.
[b] $P<0.05$, versus AgeGp3 and AgeGp4.
[c] $P<0.05$, versus AgeGp4.
[e] $P<0.05$, versus AgeGp4, chi-square test.
[f] $P<0.05$, versus AgeGp3, chi-square test.
[g] $P<0.05$, versus the other three groups, chi-square test.

Table 5 Various parameters by sleep duration groups (SLP)

Parameter	*SLPGp1 (<4 h)* (n=*13*)	*SLPGp2 (4–6 h)* (n=*75*)	*SLPGp3 (6–8 h)* (n=*337*)	*SLPGp4 (>8 h)* (n=*80*)
Age (year)	54.54±2.39	53.23±1.00[a]	50.06±0.47	51.09±0.96
T (ng dl^{-1})	379±51[b]	481±22	528±10	527±21
BioT (ng dl^{-1})	214±30[c]	258±13	276±6	276±13
IGF1 (ng ml^{-1})	198±20	215±9	204±4	184±8[d]
IGFBP3 (ng ml^{-1})	3786±263	4022±113	3789±53	3372±108[d]

Abbreviations: BioT, bioavailable testosterone; IGF1, insulin-like growth factor 1; IGFBP3, insulin-like growth factor-binding protein 3; T, testosterone.
[a, c] $P<0.05$, versus SLPGp3.
[b] $P<0.05$, versus SLPGp3 and SLPGp4.
[d] $P<0.05$, versus SLPGp2 and SLPGp3.

Table 6 Differences in various parameters between drinkers and smokers

	Group 1	Group 2	Group 3	*P*-values
Drinkers				
Status	Non-drinkers	Occasional drinkers	Regular drinkers	
n	297	22	140	
BioT (ng dl^{-1})	262±6.3	286±23	290±9.3	0.034 (Group 1 *vs.* 3)
SHBG (nmo l^{-1})	30.69±0.59	32.38±2.1	27.96±0.86	0.01 (Group 1 *vs.* 3)
IGF1 (ng dl^{-1})	208±4.1	228±14.9	186±6.2	0.003 (Group 1 *vs.* 3)
				0.009 (Group 2 *vs.* 3)
IGFBP3	3768±53	4520±190	3602±79	0.000 (Group 1 *vs.* 3)
				0.000 (Group 2 *vs.* 3)
Smokers				
Status	Non-smokers	Light smokers	Heavy smokers	
n	434	22	140	
T (ng dl^{-1})	512.9±8.8	489.4±39.3	630.7±41.2	0.005 (Group 1 *vs.* 3)
				0.013 (Group 2 *vs.* 3)
BioT (ng dl^{-1})	269±5.3	251±23	344±25	0.004 (Group 1 *vs.* 3)
				0.007 (Group 2 *vs.* 3)

Abbreviations: BioT, Bioavailable testosterone; IGF1, Insulin-like growth factor 1; IGFBP3, insulin-like growth factor-binding protein 3; SHBG, Sex hormone binding globulin; T, testosterone.

Table 7 Differences in various parameters between men who did not and men who did masturbate

	No-masturbation (n=*322*)	*Masturbation* (n=*155*)	P *values*
Age (year)	51.3±0.5	48.7±0.7	0.002
T (ng dl^{-1})	499±11	555±16	0.003
BioT (ng dl^{-1})	265±7	291±10	0.027
CoitalF (times per month)	4.50±0.16	3.61±0.26	0.004

Abbreviations: BioT, bioavailable testosterone; CoitalF, coital frequency; T, testosterone.

not. On the other hand, men who drink were associated with lower CoitalF than those who did not.

Correlations between partner relationship and other parameters

Relationship between partners had an important role in the sexual functions in men. CoitalF was significantly higher in those with very good relationship with their partners as compared to those with average relationship. On the other hand, those with very good relationship masturbated less frequently than those with average relationship (**Table 8**).

Correlations between desire for sex, penile rigidity and other parameters

Hormones were associated with some sexual functions. Men who wanted more sex than they were currently having, had higher concentrations of DHEAS than those who wanted less sex (**Table 8**). Men who wanted more sex have significantly lower CoitalF than those who were happy (**Table 8**). Men with poorer penile rigidity in their morning erection had significantly lower DHEAS than those with good rigidity (**Table 8**).

DISCUSSION

As with our earlier report,[28] age is a major determinant of many physiological parameters, including sleep, sex hormones, physical exercise and sexual activities among Singaporean men. Independent and significant declines of DHEAS and BioT, and increases in SHBG and E2 concentrations were noted even when the regression analyses were carried out with more covariates than previously included.[5,28,37–42]

Several sexual parameters declined with age. The average monthly CoitalF of men <40 years was 5.13 times per month and was 2.14 times per month in men above 60 years, which worked out to be about 62 and 26 times annually, respectively. The observed low CoitalFs in younger men concurred with the Durex Global Sex Survey (2005) in which Singapore, with an annual CoitalF of 73, was ranked the second lowest besides Japan out of more than 100 countries surveyed.[43] In contrast, Greece had the highest, with an annual frequency of 138. Although the CoitalFs of Singaporean men, by any account, were low, it must be noted that an overwhelming 68.1% were happy with their sex life and 29.9% were desirous of having more sex which was somewhat similar to that observed among Singaporean women.[44] The androgens concentrations in the Singaporean cohort were unlikely to be significantly different from those populations with higher annual CoitalFs. As was suggested earlier,[28] the low CoitalF, must not be viewed as an indication of sexual dysfunction. Furthermore, in dealing with sexual dysfunctions a low CoitalF is probably not an appropriate diagnostic criterion. These observations suggest that in evaluating sexuality, the cultural context may be of overriding importance. In some cultures, sex may be higher in the person's priority list of activities than in another culture. Singapore is a highly urbanized and competitive society. Men tend to spend most of their energy on career and family and therefore, sex may have been relegated lower in the priority list than for other cultures.[44]

Fewer older men were engaged in masturbation and for those who did, the frequencies of masturbation were lower than those in younger men. Interestingly, fewer men with higher CoitalF expressed a desire for more sex and were engaged in masturbation. On the other hand, men with lower CoitalF were more likely to engage in masturbation, suggesting that their sexual desire were not met with their partners and therefore engagement in masturbation might be their way of satisfying their unmet needs.

It was noted that significantly more men older than 60 years compared to younger men (<40 years) sleep less than 6 h nightly. This observation supports the common notion that men tend to sleep for shorter duration as they age. An adequate nightly sleep is a key component of humans' recuperation process following a day's work. This recuperation process is the engine for the regeneration of alertness required for optimal cognitive and physical functional capacities.[45] Generally, adequate sleep duration enhances alertness

Table 8 Comparisons of various parameters in Rel groups, Desire groups and Rigid groups

	Group 1	Group 2	Group 3
Partner relationship			
Status	Average	Good	Very good
n	31	181	292
Age (year)	49.84±1.56	51.98±0.65[a]	50.07±0.51
CoitalF (times per month)	3.91±0.60	3.80±0.24[a]	4.50±0.18
Masturbation time (time per month)	5.08±0.74[b]	3.18±0.33	2.25±0.31
Desire			
Status	Want more sex	Happy with present frequency	Want less sex
n	119	270	17
DHEAS (ng dl^{-1})	2677±102[c]	2377±65	1816±275
IGFBP3 (ng dl^{-1})	3833±89	3727±58	4394±232[d]
CoitalF (times per month)	3.84±0.26	4.53±0.17[e]	2.70±0.68
Rigid			
Status	Poor	Average	Good
n	3	173	268
Age (year)	52.3±4.8	51.5±0.63[f]	49.0±0.51
DHEAS (ng dl^{-1})	1732±621	2280±84[f]	2557±70

Abbreviations: CoitalF, coital frequency; DHEAS, dehydroepiandrosterone sulphate; IGF1, Insulin-like growth factor 1.
[a] $P<0.05$, *vs.* RelGp3;
[b,] $P<0.05$, *vs.* RelGp2 and RelGp3;
[c] $P<0.05$, *vs.* DesireGp2 and DesireGp3;
[d] $P<0.05$, *vs.* DesireGp1 and DesireGp2;
[e] $P<0.05$, *vs.* DesireGp1 and DesireGp3;
[f] $P<0.05$, *vs.* RigidGp3.

and performance during subsequent wakefulness.[46,47] In the present study, the observation that total T and BioT were the highest in men who slept between 6 and 8 h or more gives indirect support to the suggestion by Belenky that the optimal sleep duration is about 8 h.[48]

With the advent of the Internet era and cross-time zone global trading, many today have disrupted circadian sleep patterns, with some sleeping in the day and working in the night, whereas others have chronic sleep restriction, that is, shortened sleep duration each day. In the present study, 2.6% and 14.9% of men had acute and chronic sleep restriction, respectively. Chronic sleep restriction can affect somatic and emotional well-being,[48] but relatively little is known of its long-term effect on health. In the cohort of Singaporean Chinese men, the majority appeared to have sufficient amount of sleep, 6–8 h as was suggested by Belenky *et al.*[48]

In contrast to our earlier report on the same set of data, we noted that total T was significantly and negatively correlated with age and was as much as 39% lower in men above 60 years compared to younger men less than 40 years. The difference in results between this and our earlier analyses on the same data set was due to the inclusion of covariates such as exercise scores based on MET-min, smoking and drinking apart from %BF and sleep duration used in our earlier analysis. The observed significant decline in T with age appears to support the observation of declines in many androgen-dependent functions with age. Hence, to more accurately assess how androgens may correlate with other physiological functions, it is important that all relevant covariates must be taken into consideration in the analyses.

Several lifestyle factors could moderate some of the age-associated changes in hormone levels. As was reported earlier,[28] there was a positive association between regular sleep duration and androgen concentrations that is independent of age, %BF and other relevant covariates including MET-min scores, smoking and alcohol consumption. Men with acute sleep restriction (those who slept, 4 h daily) and those with moderate sleep restriction (those who slept between 4 and 6 h daily) had significantly lower T by 39.0% and 9.8%, respectively, and BioT by 29.0% and 7.0%, respectively, when compared with corresponding concentrations in men who slept more than 8 h. The lower androgen concentrations in men with sleep restriction may consequentially affect their androgen-dependent functions. In the present study, men with lower concentrations of T or BioT were less likely to engage in masturbation. Therefore, in men with low concentrations of androgens concurrent with poor sleep habits the promotion of better sleep hygiene represents a non-drug intervention for improving their androgen concentrations. If indeed better sleep is possible to raise endogenous T secretion by 10%–40% with its attendant episodic secretary pattern, this mode of management may be better than androgen replacement which result in elevation of T, albeit in a tonic rather than an episodic manner. However, further investigations are needed to validate such a hypothesis and perhaps also to look into how the quality of sleep might affect androgen concentrations.

Physical exercise, an important lifestyle factor, is known to have beneficial impact of health. Using the MET-min as the score for exercise intensity, the study showed that sufficiently intense physical exercise can moderate age-related changes in some physiological parameters. MET-min score reflects more accurately the intensity of the aerobic exercise as it takes into account the type of physical exercises with varying METs assigned to them as well as the duration of each exercise bout. Many earlier studies on the effects of exercise on health in men have focused on experimental effects of short-term exercise regimes, with most demonstrating that exercise bouts are associated with transient changes in sex steroids.[49–54] A few studies involving longer exercise regimes have shown positive impact on health in men.[55,56] However, there is no consensus regarding the physiological role of long-term exercise in altering sex hormone concentrations in aging men.[57–61] In the present study, it was noted that men with regular moderate to high intensity of physical exercise have significantly higher concentrations of both T and BioT, ranging from 11% to 20%, when compared to men who did not or had low intensity

exercises. Such an observation concurred with earlier studies[48,62–65] but not with another.[66] Moderate to high intensities of physical exercises were associated with higher concentrations of SHBG in agreement with an earlier study.[67] The physiological significance of such an observation is not known, except that an increase in SHBG may have a moderating influence on androgenic action. The differences in observations among these and our study may be related to several factors. Firstly, as shown earlier, sex hormones, apart from the strong association with age, could be moderated by many other factors such as sleep and %BF; hence, if these covariates of sex hormones were not taken into account in the analyses, the true association might be missed. In addition, it is noteworthy that the association between sex hormones and acute short episodic exercise regime[65,66] might be different from those in men with a lifestyle habit of regular exercise as with subjects in the present study. Furthermore, the differential associations of purely aerobic[49] and weight-bearing[65,68] physical exercises with these sex hormones must be distinguished. Overall, the present study showed that moderate to intense exercises are associated with higher levels of androgen concentrations and therefore, are beneficial to androgen-dependent functions.

High-intensity physical exercise was associated with a significantly lower %BF. At the same time %BF is correlated to T concentration; hence %BF can indirectly moderate androgenic actions in men.

The significance of the observed higher T and lower total body fat in heavy smokers as compared to non-smokers is not known. How smoking might induce a higher T levels is unclear. However, the lower total body fat might be a consequence of higher T. Likewise, the mechanism and significance of alcohol consumption-induced lower SHBG, IGF1 and IGFBP3 levels and higher levels of BioT remain unclear at the moment.

With the advent of the Internet, late-night cable shows and other distractions of modern day lifestyle, many Americans are not sleeping adequately and may be chronically sleep restricted.[69,70] There is increasing evidence indicating that chronic sleep restriction or sleeping outside normal sleep zone may be taking an unprecedented toll on Americans' health.[71] Furthermore, studies have shown that adequate good sleep is beneficial to a person's well-being.[46,47] The observation that exercise of sufficient intensity may help in falling asleep, as well as the positive association of sufficiently long duration of sleep and androgen concentrations shown in the present study, suggests that promoting healthy sleep hygiene and regular exercise may be a good modality to counter these modern interruptions of good sleep.

Relatively few studies have evaluated the association between exercise and sexual function.[72,73] It is highly possible that any association of exercise with sexual function would not be major. Therefore, inclusion of men with erectile dysfunction[72] in any such study would make differentiating the association of exercise with sexual function difficult. The present study showed that moderate to high intense exercise as a lifestyle habit was associated better sexual functioning. Significantly more men who exercised at a high level of intensity were engaged in masturbation. And significantly more men who exercised at a moderate intensity were happy with their CoitalF than men in the other three exercise groups. Men who exercised at a high level of intensity did not show such in inclination. It could be due to the negative association of older age on CoitalF. In addition, the older men's partners, as older women, may have lower interest in sex which might create a sense of unmet desire for more sex.[3] This is evident by the fact that more of the men in this group were engaged in masturbation to meet this unmet sex need. However, the mechanism for exercise-associated better sexual functions remains speculative. It could be associated with exercise-induced increases in T and DHEAS as shown in the present and an earlier study.[73]

These findings support the importance of promoting a lifestyle habit of exercise to mitigate the increase risks of having sexual and sleep dysfunctions as men age. The potential health benefits of moderately intense exercise shown in the present study concurred with the recommendation of the American College of Sports Medicine and the American Heart Association and another earlier study.[73–75]

As shown by earlier studies, neither T nor BioT was associated with CoitalF or with desire for more frequent coitus.[76,77] However, men who masturbated had higher concentrations of T and BioT. Therefore, it would appear that androgens may have limited sexual motivational effect in men as was suggested by an earlier study.[78] Differences in ours and other observations may be related to the fact that, in this study, many of the relevant covariates of both androgens and sexual functions were taken into account in the analyses, while they were not in the earlier studies. E2, on the other hand, had no significant association with sexual functions in men.

Significantly higher DHEAS concentrations were noted in men who wanted to have more sex and had very good rigidity in their morning erection. Correlation of DHEAS with sexual functions has also been shown by earlier studies.[79,80] Therefore, it appears that DHEAS may have a more significant role in some sexual functions than had been currently suggested. DHEAS is present in similar quantities in men and women and declines dramatically with age. As with men, low concentration of DHEAS has been associated with low libido and sexual dysfunction in women.[81] Hence, it is possible that DHEAS might be a common factor modulating sexual functions in both men and women. Hence, in men with low sexual function concurrent with low DHEAS levels, DHEA replacement therapy may be a viable option. As suggested earlier, despite the wide availability of DHEAS as a food supplement in the United States, no serious side events have emerged.[82] Therefore, DHEA supplementation may offer the promise of a safe and efficient replacement therapy for men with low DHEA and sexual dysfunctions, and with no known T deficiency.

Men with very good relationship with their partners had higher CoitalF and thereby lesser need for masturbation. All the evidence shown here indicates that sexual functions in men are affected by multiple factors in an interrelated manner. The mechanisms of interactions between ages, lifestyle factors, hormones and metabolic factors, are probably very complex and pose a great challenge for future studies. The results of the present study showed that in reviewing sexuality, the cultural context of the study population is upmost in importance. There is probably no single or international norm of sexual practice. Each population must be studied within their own cultural context. Aggressive promotion of pharmaceutical intervention to sexual dysfunctions without taking into consideration the cultural and psychosocial context of the population must be viewed with caution. Apart from hormonal and metabolic factors such as androgen levels, being obese, the relational factor, a major determinant for sexual function, must be taken into account in the management of sexual dysfunctions. The results support the notion that neither psychotherapy alone nor medical intervention alone is sufficient for a lasting resolution of sexual problem, and a biopsychosocial approach must be adopted.[83]

The present study also showed the complexity of the interrelatedness of many biological factors and lifestyle factors in their association with sexual functions. T and BioT concentrations are associated with some aspects of sexual motivation. SHBG is correlated with T and BioT. SHBG was associated with %BF, and therefore, indirectly may be related to T *via* its association with SHBG.

In summary, the present study consisted of men including those in the older age groups who were healthy. Therefore, the associations

noted among the various parameters were not confounding with any significant comorbidities. In addition, the use of multiple regression analyses had adjusted the correlation among the various possible covariants, thereby enhancing the independent nature of the correlation analyses. The present study shows that age is a major determinant for many physiological parameters, including sleep, hormonal and metabolic parameters, some lifestyle factors and sexual activities. As with many other studies, T, BioT and DHEAS concentrations decreased with age, while E2 and SHBG and %BF increased with age. The intricate associations among hormonal, metabolic and lifestyle factors shown in the present study suggest the importance of evaluating low hormonal states in the light of these interrelationships. The fact that high-intensity exercise and longer duration of sleep were associated with higher concentrations of T and BioT suggests that the promotion of good sleep hygiene and regular high intensity of exercise may be effective non-drug adjunct management modalities for men with late onset hypogonadism. Besides, one of the concerns in androgen replacement therapy is the uncertainty of the long-term usefulness of androgen replacement which provided widely varying non-episodic androgen concentrations, as opposed to the lower concentration, but nevertheless episodic endogenous secretion in men with late-onset hypogonadism.

T was shown to be associated positively with men who were engaged in masturbation. It would appear that it may have a limited role as a motivational signal for sexual function in men. E2 was not associated directly with any of the sexual functions evaluated. DHEAS, on the other hand, appears to have a greater role as a sexual motivational signal than previously suggested. The possibility of replacing DHEA in men with low sexual functions concurrent with low DHEAS/DHEA levels needs to be explored in well-designed studies in the future.

Older Singaporean men tended to sleep for shorter duration, but exercised more intensely than younger men. Coital and masturbation frequencies decreased with age, and a significantly greater number of younger men were engaged in masturbation. The average CoitalF for the Singaporean men was very low, a result that is also reflected in the 2005 Durex Global Sex Survey in which Singapore was placed the second lowest among more than 100 countries surveyed. However, the low CoitalF cannot be taken as an indication of sexual dysfunction as close to 70% of men were happy with their sex life. The results suggest that when reviewing the sexuality, the cultural context of the population must be taken into account. Apart from the cultural context, relationship between the partners is a key determinant of sexuality in men. Clearly, therefore, both biological and psychosocial factor, interact with each other to influence sexual functions in men. It is therefore unlikely that either purely pharmacological or psychosocial approach would lead to lasting resolution to sexual dysfunctions in men. A biopyschosocial approach is the modality of choice.

AUTHOR CONTRIBUTIONS

VHHG designed and performed experiments, analysed data and wrote the paper; TYYT collate the data and kept the database.

COMPETING FINANCIAL INTERESTS

The authors declare no competing financial interests.

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