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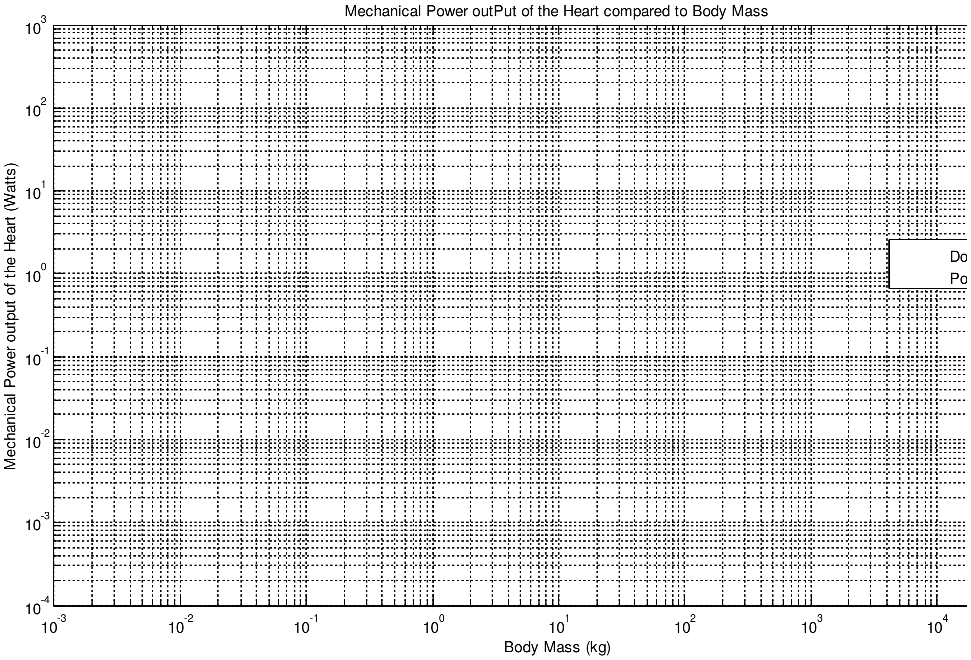
Mechanical Power Output of the heart it watts for different species:

```
clear all; close all;
clc;

dobson_body_mass = [0.002 0.03 0.3 70 4000 100000 ];
dobson_mech_power = [0.00032452 0.00290472 0.0188062 1.53216 40.698 558.6];
dobson_required_power = 10*dobson_mech_power;
dobson_litres_oxygen_per_min = dobson_required_power*60/(4.8*4184);

popovic_body_mass = [0.028 0.272  3.01 26.6 70.2];
popovic_mech_power = [0.002766631 0.013752884 0.098710938 1.102 1.273331913];
popovic_required_power = 10*popovic_mech_power;
popovic_litres_oxygen_per_min = popovic_required_power*60/(4.8*4184);

figure;
loglog(dobson_body_mass, dobson_mech_power,popovic_body_mass,
popovic_mech_power);
grid on;
title('Mechanical Power outPut of the Heart compared to Body Mass');
xlabel('Body Mass (kg)');   ylabel('Mechanical Power output of the Heart
(Watts)');
legend('Dobson Data', 'Popovic Data');

% First number is slope, second is intercept.... y = m*x+b
% 10^(log(x^m +b) =10^b*10^log(x^m) = 10^b * x^m
polyfit(log10(dobson_body_mass),log10(dobson_mech_power),1)
polyfit(log10(popovic_body_mass),log10(popovic_mech_power),1)



d_mech_power = [1.526 1.308 6.335];
d_required_power = 10*d_mech_power;
d_litres_oxygen_per_min = d_required_power*60/(4.8*4184);

oxygen_used_by_heart = [0.31, .33,2.55];
percent_used = 100*d_litres_oxygen_per_min./oxygen_used_by_heart
```

Dobson Species	**Power in Watts**
Shrew	0.00032452
Mouse	0.00290472
Rat	0.0188062
Human	1.53216
Elephant	40.698
Blue Whale	558.6

Popovic Species	**Power in Watts**
Mouse	0.002766631
Rat	0.013752884
Rabbit	0.098710938
Dog	1.102
Human	1.273331913



Power Law Scaling Exponents

Finding the Power Law Scaling Exponents that Govern the Relationship between body mass and mechanical power output of the heart. Assume First number is slope, second is intercept....

y = m*x+b

10^(log(x^m +b) =10^b*10^log(x^m) = 10^b * x^m

Dobson data: exponents are 0.8096 and -1.3043 for m and b respectively

Popovic data: exponents are 0.8288 and -1.3261 for m and b respectively

The percent difference between these exponents is 2.3% and 1.64%

Conversion of Mechanical Energy into Work

Dobson Species	**Required Energy/time in Watts**	**Litres of O_2 required /min**
Shrew	0.0032452	9.69526768642447e-06
Mouse	0.0290472	8.67805927342256e-05
Rat	0.188062	0.000561848709369025
Human	15.3216	0.0457743785850860
Elephant	406.98	1.21588193116635
Blue Whale	5586	16.6885755258126

Effects of Exercise on Values of Mechanical Power Output

Condition	Mechanical Power Output (W)	Required Energy/time (W)	Required Litres of O_2/min	% O_2 used by heart
Supine at Rest	1.526	15.26	0.0456	14.7
Upright at Rest	1.308	13.08	0.0391	11.84
Peak Exercise	6.335	63.35	0.1893	7.42

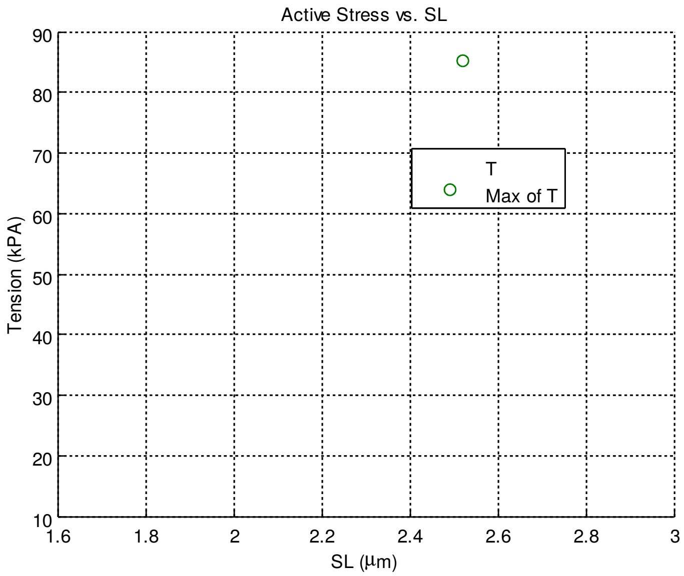
The mechanical power output of the supine at rest was .4% error off of the Dobson data, and the upright at rest was 14.6% off of the Dobson data. The differences arise from the required blood pressure to overcome the forces of gravity when the patient is upright vs. supine.

When exercise ramps up, the required energy as well as the required oxygen for the heart skyrockets, but the actual percent of the O_2 taken in by the body decreases because the rest of the body and muscles require a large amount of oxygen as well. For trained athletes, the large discrepancy between the rest and peak exercise states would be different. The actual values might be higher, because the trained athlete has larger or stronger cardiac muscle that demand more, but the % difference between rest and peak wouldn't be as high as in the normal adult.

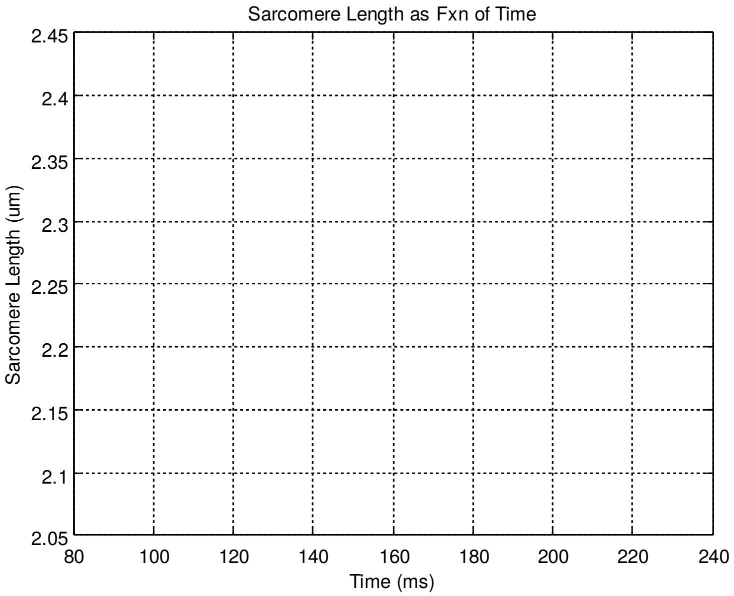
Active Stress in the Cardiac Muscle Fiber Direction

```
close all; clear all; clc;
% t= ;
% t_a =  ;           %total activation time
% t_star = t/t_a;    %normalized time
% tau = t_max/t_a;   %normalized time of peak activation

f = 1;              %
B = 69;             %constant (kPa)
SL = linspace(1.7, 2.8, 10000);      % sarcomere length
SL_z = 1.6;         %muscle fiber stretch ratio at which no active force obtained
SL_o = 2.4;         %msucle fiber stretch ratio that yields MAX ACTIVE FORCE
SL_rest = 2;        %sarcomere length in the unloaded muscle
v = 0;              %the shortneing velocity (um/s)
v_max = 1/1000 ;    %shortening velocity(um/s) at which external load is zero

T = f.*B.*((1-((SL-SL_o).^2./((SL_z-SL_o).^2))).*(SL./SL_rest)).*(1-v./v_max); %active stress

figure; hold all;
plot(SL,T); grid on;
title('Active Stress vs. SL');
xlabel('SL (\mum)'); ylabel('Tension (kPA)');
T_max_x = SL(find(T==max(T)));          %sarcomere length at T_max
T_max = max(T);                         %maximum active stress achieved
scatter(T_max_x,T_max);
legend('T', 'Max of T');
```

%Maximum active stress achieved was 84.96 kPa and occurred at 2.5238 µm.



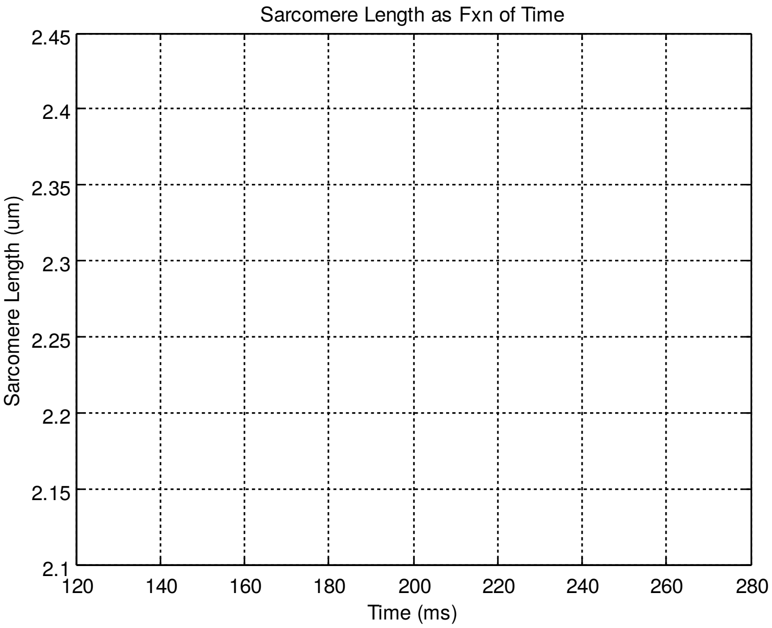
```
clear all; close all; clc;
T=40;
t=80;               %msec
t_a =  500;         %total activation time
t_max = 100;
t_star = t/t_a;     %normalized time
tau = t_max/t_a;    %normalized time of peak activation

if t_star<=tau
    f = sin(pi*t_star/(2*tau))^2;          %
else
    f = sin(pi*(1-t_star)/(2*(1-tau)))^2;
end
B = 69;             %constant (kPa)
SL = 2.4;           %sarcomere length (um)
SL_z = 1.6;         %muscle fiber stretch ratio at which no active force
obtained
SL_o = 2.4;         %msucle fiber stretch ratio that yields MAX ACTIVE FORCE
SL_rest = 2;        %sarcomere length in the unloaded muscle
% v = 0;            %the shortneing velocity (um/s)
v_max = 6;     %shortening velocity(um/s) at which external load is zero

syms vv
v = solve (T == f*B*((1-((SL-SL_o)^2/((SL_z-SL_o)^2)))*(SL/SL_rest))*(1-
vv/v_max),vv )

display(v);
dL= v*(230-80)/1000;

answer=2.4-dL %1.9807 um this is sarcomere length at 230ms
```



```
clear all; close all; clc;
initial_SL = 2.4;
fxnName= 'ejection';
tspan= [80 230];
[Tout, SL] = ode45(fxnName, tspan,initial_SL);
figure;
plot(Tout, SL);
grid on;
title('Sarcomere Length as Fxn of Time');
xlabel('Time (ms)');
ylabel('Sarcomere Length (um)');
clear all; close all; clc;
initial_SL = 2.4;
fxnName= 'ejection';
tspan= [120 270];
[Tout, SL] = ode45(fxnName, tspan,initial_SL);
figure;
plot(Tout, SL);grid on;
title('Sarcomere Length as Fxn of Time');
xlabel('Time (ms)');
ylabel('Sarcomere Length (um)');
```

ejection fxn

```
function dSLdt = ejection( t,SL )
%UNTITLED4 Summary of this function goes here
%   Detailed explanation goes here
T=40;
t_a =  500;          %total activation time
t_max = 100;
t_star = t/t_a;      %normalized time
tau = t_max/t_a;     %normalized time of peak activation

if t_star<=tau
    f = sin(pi*t_star/(2*tau))^2;          %
else
    f = sin(pi*(1-t_star)/(2*(1-tau)))^2;
end
B = 69;              %constant (kPa)
% SL = 2.4;          %sarcomere length (um)
SL_z = 1.6;          %muscle fiber stretch ratio at which no active force
obtained
SL_o = 2.4;          %msucle fiber stretch ratio that yields MAX ACTIVE FORCE
SL_rest = 2;         %sarcomere length in the unloaded muscle
v_max = 6/1000;      %shortening velocity(um/s) at which external load is zero


dSLdt = v_max.*((T./(f.*B.*(1-((SL-SL_o).^2./((SL_z-
SL_o).^2))).*(SL./SL_rest)))-1);

end
```


Sarcomere Length as Fxn of Time
Sarcomere Length (um)
2.45
2.4
2.35
2.3
2.25
2.2
2.15
2.1
120
140
160
180
200
220
240
260
280
Time (ms)