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Proprioceptive Isokinetic Exercise Test

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Proprioceptive Isokinetic Exercise Test

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Summary

Proprioception, the reception of stimuli within the body that indicate its position, is an important mechanism for optimal human performance. People exposed to prolonged bed rest, or other deconditioning situations, experience reduced proprioceptor and kinesthetic stimuli (Freeman 1967, 1965; Money 1985). A new proprioceptive test has been devised that utilizes the computer-driven LIDO isokinetic ergometer at Loredan Biomedical, Inc., in Davis, California (see fig. 4). A general overview of the logic, software, and testing procedure for this proprioceptive test, which can be performed with the arms or legs, is given.

Overview

An isokinetic exercise load is defined here as a function of position and direction of rotation of the ergometer arm; it is sensed by an hydraulic valve opening that regulates velocity to a predetermined setting (fig. 1(a)). Subsequently, this load is applied in a predictive or randomized fashion so that replication of effort by the test subject is required to maintain the same conditions of position as a function of time, or of torque as a function of position (see fig. 1(b)). The precision of replication of a position or torque is displayed graphically on a video screen where the subject can see it (fig. 5). In addition the ergometer load, presented to the subject via the ergometer arm, is varied in a pseudo-random fashion and imposes unexpected loads superimposed on the basic load profile. The subject is asked to maintain position or torque with the horizontal line (figs. 1(c) and 5), which requires a compensatory response of the subject's limb to the unexpected load variations indicated by moving vertical bars. A scoring system gives a percentage of correct responses.

Preparing for a test or training session (fig. 2)– First, the softstops (a feature that limits range of motion to preset limits) and velocity limits are set via the computer. As these limits are approached during a test, isokinetic velocity regulation is lowered as a function of position by constraining angular deceleration to a predetermined value, thereby avoiding the impact of an abrupt termination of motion.

Performing a test or training session (fig. 3)– Next, a few repetitions of isokinetic exercise are performed at a submaximal level of effort. The first complete repetition is a warmup. Subsequently, six numerical arrays of 32 values each are defined. These arrays are addressed by time at a rate of 6.25 Hz and filled with current values for torque, angle, and load setting. Each direction of movement (as defined by torque) has its own set of arrays. Torque and angle values are measured directly at the controller. The load setting is the signal sent to the electrically controlled valve to regulate velocity. Time is measured from the last turnaround, as defined by change in sign of the torque.

Analysis of these arrays allows for derivation of polynomial functions relating torque as a function of angle, angle as a function of time from turnaround, and valve opening as a function of angle. These functions are defined for each direction of limb movement. The polynomials derived are the unique 4th-order polynomials whose sum of squared deviation from the measured data is a minimum. These polynomials provide smooth approximations to average performance during the time the arrays are being generated.

Next, the operator selects the training parameter, position, or torque. A perturbation pattern is selected which presents either discrete perturbation events of selected amplitude but random time and duration, or a continuous perturbation pattern with a controlled spectral profile. ("Continuous" is used here to describe an approximation to a continuous function of time by 100-Hz, 8-bit digital representation driving a valve with a frequency response of about 30 Hz). Pascal listings showing the methods of generation are included as appendix 1.

Testing or training for position regulation– If the chosen parameter for training or testing is position as a function of time, then an histographic, parallel display of goal

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and actual positions appears on the video screen for biofeedback. Scoring is computed as 100 times the absolute value of the difference between actual position and goal position, as measured from turnaround, divided by goal position. The displayed score for a repetition is the average score over the middle 60% of the range of motion. The overall score is the average of these scores for the session. A perfect score is 100, corresponding to an exact match of goal and performance during the middle 60% of the range of motion.

Testing or training for torque regulation– If the chosen parameter of training or testing is torque as a function of position, then an histographic, parallel display of goal and actual torque appears on the screen for biofeedback. Scoring is computed as 100 times the absolute value of the difference between actual torque and goal torque, divided by goal torque. The displayed score for a repetition is the average score over the middle 60% of the range of motion. The overall score is the average of these scores for the session; a perfect score is 100, corresponding to an exact match of goal and performance during the middle 60% of the range of motion.

Spectral analysis– The software includes methods for determining the spectral distribution of energy in the generated errors over a band of 1 to 10 Hz. The lack of reproducible results indicates that further development is required.

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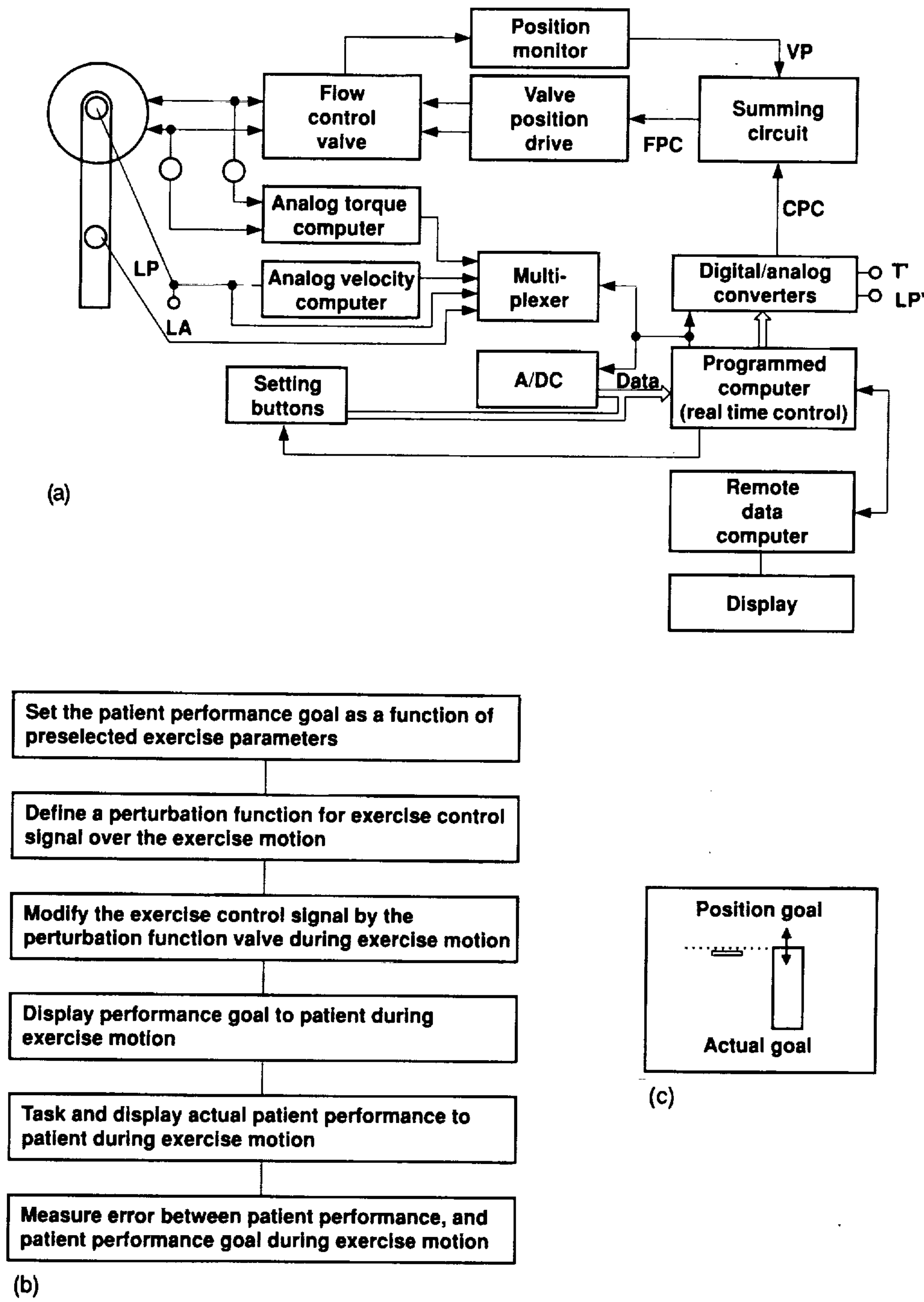

Figure 1. (a) Schematic of the ergometer and computer interfaces. (b) Logic diagram for subject test procedure. (c) Subject biofeedback video diagram.

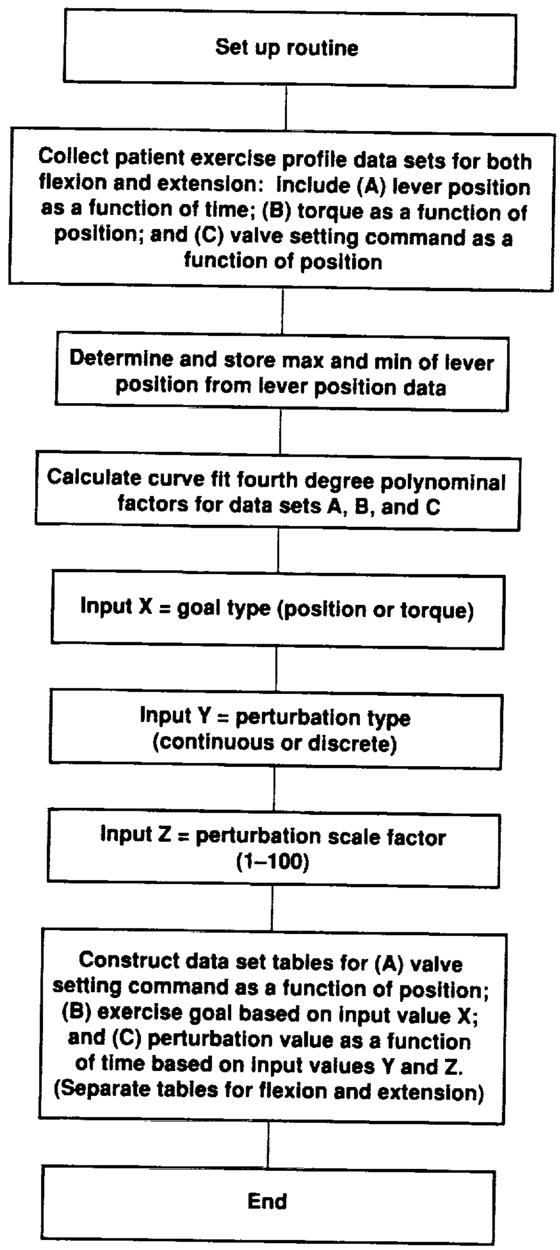

Figure 2. Computer set-up routine for a subject's test or training session.

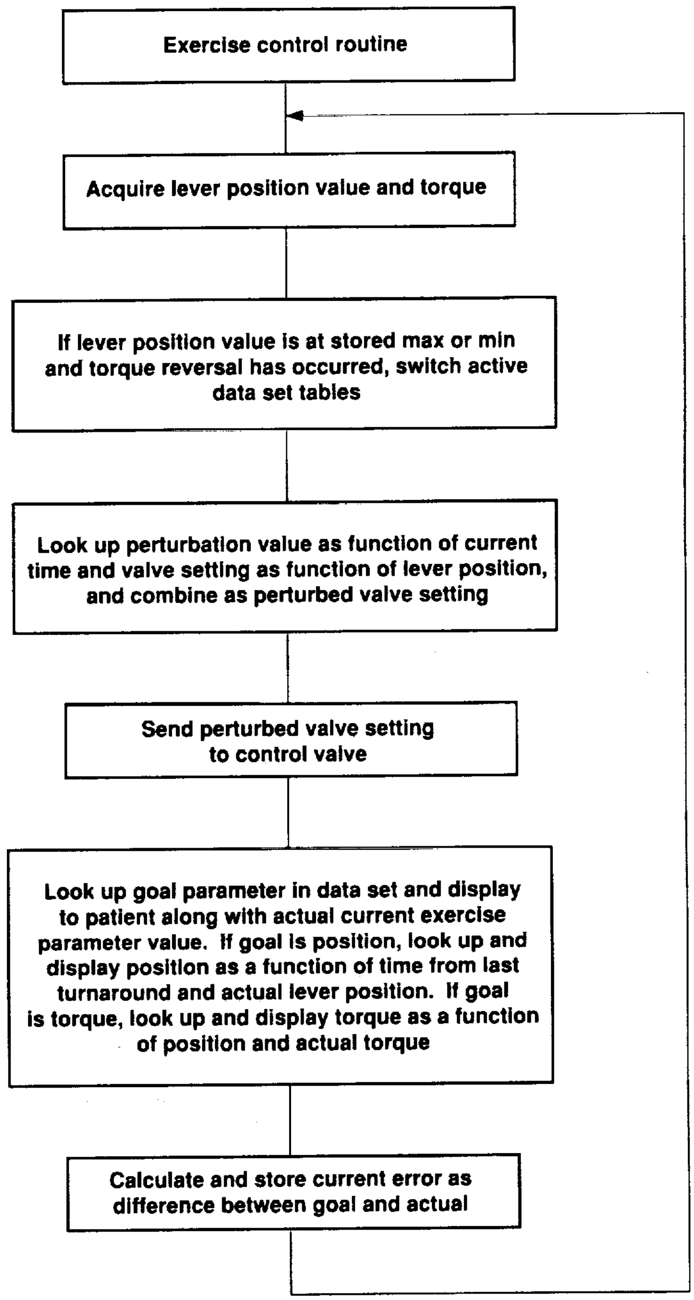

Figure 3. Computer control routine for a subject's test or training session.

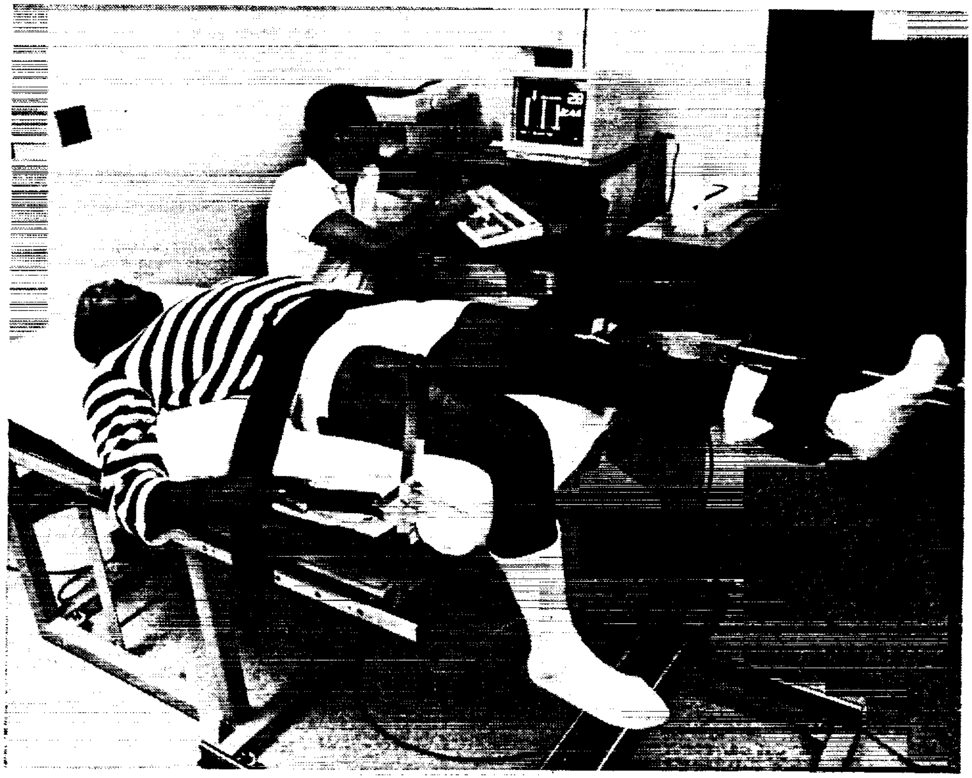

Figure 4. Test subject in position to perform proprioceptive test.

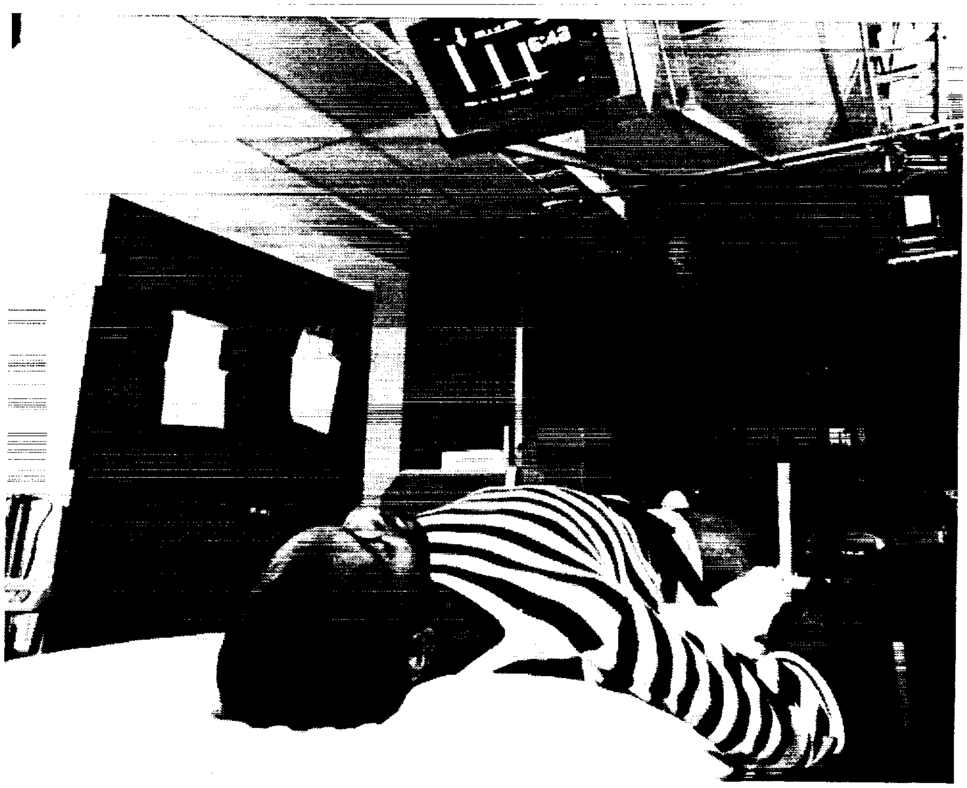

Figure 5. Biofeedback video display above subject's head.

Appendix 1

The following two listings, written in Borland Turbo Pascal, indicate the methods used to generate the continuous and discrete psuedo-random functions, respectively.

```
{$u+}
var
      n,k,p,q:integer;
      r1,r2:array[0..1025] of real;
      r: array[0..1023] of integer;
      x:real;
      table:file of integer;

procedure filter1;
      begin
            for n:=1 to 1025 do
                  r2[n]:=r2[n-1]+(r2[n]-r2[n-1])*3.1416/50;
      end;
      {filters r2 with a time constant of 2pi, a -3db point of          1Hz}

procedure filter2;
      begin
            for n:=1 to 1024 do
                  r2[n]:=r2[n-1]+(r2[n]-r2[n-1])*3.1416/5;
            end;
      {filters r2 with a time constant of 0.2Hz, a-3db point of         10Hz}
procedure loadr1;
      begin
            for n:=0 to 1025 do
                  begin
                        r1[n]:=random-0.5;
                        r2[n]:=r1[n];
                  end;
      end;
      {loads r1 and r2 with random reals}

procedure circular;
      begin
            loadr1;
            filter1;
            r1[0]:=r2[1025];
            for n:=0 to 1025 do r2[n]:=r1[n];
{the above 2 statements modify the first number in r1 so that the 1025th number
after filter1 will be almost equal to the 0th number. Thereafter r2 is made equal
to r1 and the refilterled.}

            filter1;
            for n:=0 to 1024 do r1[n]:=r2[n];
            filter2;
            r1[0]:=r2[1024];
            for n:=0 to 1024 do r2[n]:=r1[n];
            filter2;
```

```
{the same procedure is repeated with filter2}
      end;

procedure load;
      begin
            for n:=0 to 1023 do r[n]:=round(4096*r2[n]);
      end;

procedure display;
      begin
            graphcolormode;
            k:=0
            repeat
                  gotoxy(1,1);
                  write(k,' ');
                  for n:=k to k+320 do
                        begin
                         if n>1023 then p:=n-1024 else p:=n;
                         if p-20<0 then q:=p+1004 else q:=p-20;
                         plot(n-k, 100-r[q] div 16,0);
                         plot(n-k, 100-r[p] div 16,1);
                        end;
                  k:=k+20;
                  if k>1023 then k:=k-1024;
            until 1=0;
      end;

procedure disker;
var
      hi, low : integer;
      span : integer;
      begin
            assign(table,'crand.dat');
            rewrite(table);
            hi := r[0];
            low := hi;
            for n:=0 to 1023 do
            begin
                  if r[n] > hi then hi := r[n];
                  if r[n] < low then low := r[n];
            end;
            span := hi - low;
            writeln(span);
            delay(2000);
            for n:=0 to 1023 do
            begin
                  r[n] := round (r[n]*(256/span));
                  if r[n] > 255 then r[n] := 255;
                  if r[n] < -255 then r[n] := -255;
                  write (table, r[n]);
                  writeln(r[n]);
            end;
            close(table);
      end;
```

```
begin
      circular;
      load;
      disker;
      display;
end.
```

```
{$u+}

var
      n,k,p,q,temp,templ:integer;
      r: array[0..1023] of integer;
      rl:array[0..1024] of real;
      table:file of byte;
      r2 : byte;

procedure load;
      begin
            for n:=0 to 1024 do rl[n]:=random;
            temp:=0;
            for n:=800 to 1024 do
                  begin
                        if rl[n]>0.97 then temp:=256;
                        if rl[n]<0.03 then temp:=-256;
                  end;
            for n:=0 to 1023 do
                  begin
                        if rl[n]>0.97 then temp:=256;
                        if rl[n]<0.03 then temp:=-256;
                  end;
            end;

procedure display;
      begin
            graphcolormode;
            k:=0;
            repeat
                  gotoxy(1,1);
                  write(k,' ');
                  for n:=k to k+320 do
                        begin
                         if n>1023 then p:=n-1024 else p:=n;
                         if p-20<0 then q:=p+1004 else q:=p-20;
                         plot(n-k,100-r[q] div 16,0);
                         plot(n-k,100-r[p] div 16,1);
                        end;
                        k:=k+20;
                        if k>1023 then k:=k-1024;
                  until 1=0;
            end;
```

```
procedure disker;
      begin
            assign(table,'drand.dat');
            rewrite(table);
            for n:=0 to 1023 do
                  begin
                        if r[n] > 127 then r[n] := 127;
                        if r[n] < -127 then r[n] := -127;
                        r2 := lo(r[n]);
                        write(table, r2);
                        writeln(r2);
                  end;
                  close(table);
            end;
      begin
            load;
            disker;
            display;
      end.
```

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Proprioception, the reception of stimuli within the body that indicates position, is an important mechanism for optimal human performance. People exposed to prolonged bed rest, microgravity, or other deconditioning situations usually experience reduced proprioceptor and kinesthetic stimuli that compromise body balance, posture, and equilibrium. A new proprioceptive test is described that utilizes the computer-driven LIDO isokinetic ergometer. An overview of the computer logic, software, and testing procedure for this proprioceptive test, which can be be performed with the arms or legs, is described.

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