# Dynamic Model of Temporary Work Disability due to Musculoskeletal Diseases

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## Introduction

Mathematical models and computer simulations have become important experimental tools in many fields to analyse and resolve multifactor problems and to explain the behaviour of complex systems. Disability is a dynamic status that can be represented as a system of several interrelated factors changing in time and having an continual effect on each other. **System dynamics (SD)** techniques consider important the temporal information reflecting the evolution with the time of the system's variables behaviour, and this allows to deepen into the problems knowledge more than statistical analysis do. Up to now, SD techniques have not been applied to study disability produced by **musculoskeletal diseases (MSD)**.

## Objectives

To develop a dynamic model to:

**1)** Simulate the evolution of **temporary work disability** (**TWD**) episodes due to MSD.

**2)** Analyse the usual evolution of MS-TWD episodes and de effect of a specific medical intervention in their evolution towards **permanent disability (PD)** or recovery

## Material y Methods

The results of a two years prospective controlled cohort study -described in detail in poster "Work disability related to Musculoskeletal disorders: An intervention from public health perspective" by J.A. Jover et al. Nº - have been the basis to develop and assess a dynamic model of musculoskeletal disability.

This study compared the effect of standard medical care versus an specific return to work intervention on the duration of TWD episodes and their evolution to PD, and was conducted on an urban population of Madrid with 610,000 active workers. All patients with new onset not traumatic or surgical TWD episodes due to MSD were enrolled during a year and randomized into two groups: 1) **Control (CG)**: following standard care management, and 2) **Intervention (IG)**: enrolled in a specific return-to-work program. Patients were followed for another complete year and successive TWD episodes were treated avoiding crosses of patients between the groups. The minimum follow-up period of any given patient was one year.

All the MSD-TWD episodes in both groups have been analysed using SD techniques in order to explain how medical intervention can reduce the duration of episodes and the number of patients going to PD.

## Results (I)

A total of **13,077 patients** (7,805 in CG and 5,272 in IG) suffered **16,297 MS-TWD episodes** (9,651 in CG and 6,646 in IG) during the study which have been registered in respective **survival curves** in **Figure 1**. Each survival curve shows the evolution of TWD episodes (% episodes still unfinished) during one-year period since the starting of each one. Most patients (**89% in CG and 94% in IG) returned to work within first two months**, but those returning to work after six months (2.5% in CG and 0.7% in IG) were unusual, with many of them being off work for the complete 18 months period allowed by the administration.

The **average duration** of TWD episodes was **41.3 days in CG and 25.6 days in IG** ($p < 0.001$). The intervention obtained a **relative efficacy** on 38% (percentage of days saved by episode in IG with respect to CG). The intervention also produced a decrease in the number of patients initiating PD-evaluation process and receiving any form of long-term disability compensation or early retirement (**Table 1**).

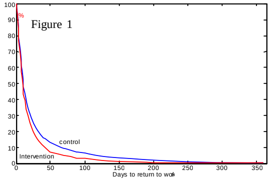
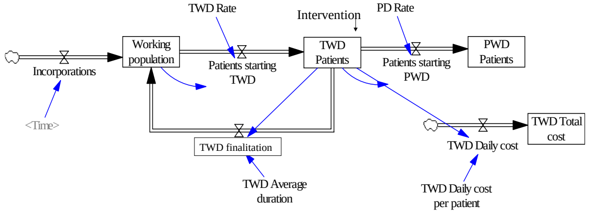



**Table1**: Evolution to Permanent Disability (PD) by groups: n (%)

| | Control | Intervention |
|---|---|---|
| Patients proposed for PD | 187 (1.9) | 71 (1.1) |
| PD proposal accepted | 114 (61.0) | 44 (62.0) |
| Pd proposal rejected | 65 (39.0) | 23 (38.0) |

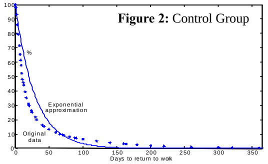
**Figure 1**: Survival curves showing the rate to return to work during one-year period, by study group. The small area under the IG survival curve illustrates the **efficacy of the program**: IG patients were able to return to work earlier than CG patients.

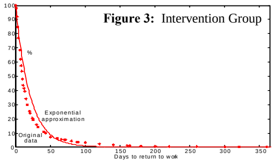
## Results (II): Elemental Model




The mathematical function that better fit the survival curves is the **exponential** $y(t) = 100\ e^{-\frac{t}{\tau}}$

because it takes the value 100 at t=0, becomes zero when t becomes infinite and it is monotonous decreasing. This model has a very simple **hydraulic analogy**: y (t) is the instant level of a tank that was full (100%) of water and finished empty (0%) because the tank has a valve and the outflow rate of water through the valve has been proportional to the level of the tank. Opening more or less the valve it s possible to accelerate or to break the emptying of the tank. Using this simile for the TWD process, the medical intervention can be simulated as the manipulation of the valve. The only parameter of the function, **the time constant τ , would mean the average duration of the TWD processes**




The **Figures 2 and 3** show the original data and the two exponentials that had better approximate the survival curves of the groups. The time constants of these functions are respectively 29.5 and 20.6 days, and have been obtained to include the same area (A = 100 τ) that the original survival curves.

The functions are no quite close to **the survival curves** because these **do not show a perfect exponential shape**.. Therefore, we conclude that the **TWD processes are more complex; their dynamics cannot be described by a single exponential equation and cannot be characterized by a single time constant**

## Results (III): The dynamic model

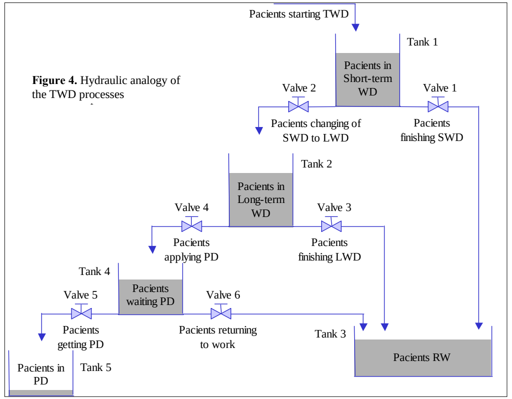


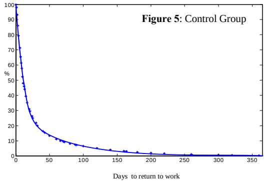

**Figure 4.** Hydraulic analogy of the TWD processes

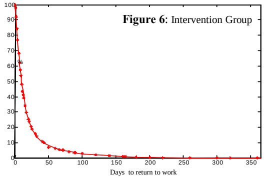
**Table 3**: Dynamic model's variables

| Name | Type | Meaning |
|---|---|---|
| PSWD | Level | Patients in Short-term Work Disability |
| PLWD | Level | Patients in Long-term Work Disability |
| PWPD | Level | Patients Waiting for the Permanent Disability evaluation |
| PRW | Level | Patients that have Returned to Work after a short-term or long-term work disability or after wait without success the permanent disability evaluation |
| PPD | Level | Patients that have got the Permanent Disability after a long-term working disability and wait with success the evaluation |
| PSTWD | Rate | Patients/day that Start a Temporary Work Disability |
| PFSWD | Rate | Patients/day that Finish their Short-term Work Disability |
| PFLWD | Rate | Patients/day that Finish their Long-term Work Disability |
| PS2LWD | rate | Patients/day that change of Short-term to Long-term Work Disability |
| PAPD | rate | Patients/day that Apply for Permanent Disability and therefore have lost the consideration of patients in long-term work disability |
| PGPD | rate | Patients/day that Get the Permanent Disability |
| PNGPD | rate | Patients/day that do Not Get the Permanent Disability |
| PFTW | auxiliary | Total number of Patients/day that Finish their Temporary Work Disability |
| PTWD | auxiliary | Total number of Patients in Temporary Work Disability |
| ADSWD | parameter | Average Duration of the Short-term Work Disability |
| ADLWD | parameter | Average Duration of the Long-term Work Disability |
| PPS2L | parameter | Percentage of Patients/day that were considered in Short-term work disability and in the future will be considered in Long-term disability |
| AWTPD | parameter | Average Waiting Time for the Permanent Disability evaluation |
| PPAPD | parameter | Percentage of Patients/day in long-term work disability that Apply for Permanent Disability |
| PUPD | parameter | Percentage of Unfavourable Permanent Disability evaluations |

| | Control | Intervention |
|---|---|---|
| **ADSWD** | 16.34 | 14.27 |
| **ADLWD** | 74.64 | 56.43 |
| **PPS2L** | 6.95 | 3.47 |
| **PPAPD** | 0.14 | 0.16 |

**Table 2**: **The tuned parameters** of the dynamic model in both groups show how the medical intervention affects the course of TWD processes.
**The two types of patients in the IG return to work earlier than CG-patients do**: the average duration of the short-term WD is two days lesser in the IG, and the long-term WD is eighteen days shorter than in CG.
**In CG there is the twice of patients/day that change of short-term to long-term disability comparing with the IG.** The percentage of patients/day applying for PD is similar in both groups




The **Figures 5 and 6** show the original data and the best survival curve approximation by the dynamic model in both groups. These good results confirm that the dynamic model proposed and its hydraulic analogy in Figure 4 are an excellent approach to the TWD process.

## Conclusions

**The SD approach to the TWD allows explaining how the medical team affects the TWD episode evolution and can improve its dynamic characteristics.**

**▪ Specific medical intervention acts decreasing the average duration of short and long-term work disability episodes, decreasing the percentage of patients that get the PD and increasing the percentage of patients that return to work.**
**▪ The good approximation of the survival curves in control and intervention groups have allowed validating the dynamic model. This model and its parameters may be used by the medical team to study the disability due to MSD, to evaluate the cost and the effectiveness of their decisions, and to explore the best scenario.**