griPASTA: A hacked kitchen scale for quantification of grip strength in rodents

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Abstract

Assessment of neuromuscular function is critical for understanding pathophysiological changes related to motor system dysfunction in numerous animal models of disease. Among numerous methods used for quantification of grip performance in rodents, gauge-based grip strength meters seem to provide the most reliable results, however such instruments are unaffordable by many laboratories. Here we demonstrate how to build a grip strength apparatus for rodents from scratch using a digital kitchen scale, an empty cage and a microcontroller. griPASTA is completely open-source so both hardware and software can be easily modified by the end user to best fit the specific experimental protocols.

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Introduction

Assessment of muscle strength is critical for understanding neuromuscular function in rodents. As a plethora of rodent models demonstrate impaired neuromuscular function, sensitive methods for objective quantification of muscle strength is a topic of interest for many research groups. Over the years, numerous tests have been proposed for in vivo muscle strength assessment such as inverted screen[1], scale collector weight lifting[2], wire hang[3], treadmill[4], vertical pole[5], swimming endurance and grip strength test[6]. The grip strength test is favoured by most as it is fast, convenient and introduces less stress in comparison with other tests[6]. Additionally, its importance has been recognized by authorities so the test is included both in the US Environmental Protection Agency Functional Observational Battery (US EPA FOB) and OECD guidelines for neurobehavioral toxicity screening[7]. Several commercial strain gauge-based grip strength meters suitable for precise and objective quantification of grip strength are available on the market, however they are unaffordable by many laboratories. As a consequence, researchers usually opt out for cheap semi-quantitative solutions for grip performance evaluation. We believe money should not stand in the way of scientific accuracy (or science in general) so we designed a simple open source platform that combines affordability, availability and simplicity of semi-quantitative grip strength tests, and precision, robustness and informativeness of the quantitative strain gauge-based methods.

Concept and Hardware

Commercially available equipment for measurement of grip strength in rodents exploits strain gauges, sensors that convert force into a change in electrical resistance that can be easily measured. The exact same force-to-resistance conversion method is unknowingly used by many every day as cheap commercial kitchen scales exploit the very same principle for weight estimation as costly equipment for neuromuscular function assessment. We have previously proposed a method for repurposing widely available digital scale strain gauges for assessment of acoustic startle response and prepulse inhibition sensorimotor gating phenomenon in rodents in “A complete hardware and software cookbook for PASTA (Platform for Acoustic STArtle)” [8]. Here, we propose a hacked kitchen scale can also simply be transformed into a platform for quantification of grip strength. A setup for measurement of grip strength in rodents consists of two main parts: A hacked digital kitchen scale connected to a computer[8] and a weighted mouse cage used as a grip test platform.

A hacked kitchen scale

For detailed instructions on how to hack a kitchen scale and connect it to a computer

as well as for free open-source software packages for data extraction and visualization please see Virag et al.[8]. In brief, a digital kitchen scale is opened and strain gauge load cells are identified and connected to a readily-available HX711 circuit board modified by reconnecting the RATE pin to VCC to enable 80 samples per second sampling rate mode of the integrated circuit. The HX711 is connected to a microcontroller that acts as a communication bridge between the kitchen scale and the computer through a USB connection (**Fig 1A-C**). We used a *NodeMCU ESP-32S,* but other AVR-based Arduino microcontroller boards may be used just as well.

A grip test platform

In order to extract grip strength data from a kitchen scale we constructed a grip platform for rats. We wanted to use something readily available in most laboratories equipped for experiments with laboratory animals so we used a mouse cage with a cage lid being used as a test surface and several boxes of old histological slides used as a weight to stabilize the platform. In order to reduce the variability of animal gripping patterns, duct tape is placed on part of the cage lid making only some grids available for the animals to hold onto. The whole system is fixed onto the PASTA platform with duct tape or reusable putty-like pressure-sensitive adhesive (eg. Patafix, UHU, Germany).

Software

In order to extract data from the platform we used a custom Python script written for general purpose experimentation with PASTA called PASTAgp (PASTA general purpose script), with a modified Y scale for grip testing. Once loaded, the script asks for the ID of the animal and initiates a pyqtgraph real-time plot of the scale-extracted data (**Fig 1C**). When the recording is done, the script automatically saves data in comma separated value format in the predefined directory, using the ".pasta" extension (ID.pasta). The whole code is freely available under the GPL3 copyleft licence in the PASTAgp GitHub repository[9].

An example of the griPASTA experimental protocol for grip strength assessment in rats

The griPASTA platform is completely open-source so both hardware and software are easily modifiable to best fit a wide variety of specific experimental purposes. In further text we describe the experimental protocol used in the proof-of-concept study. Briefly, a modified kitchen scale (PASTA) is placed on a clean and flat surface and connected to a computer through a USB. A grip test platform is prepared by placing a weight in a clean mouse cage. Precise quantification range of the kitchen scale we

used (Vivax Home KS-502T, Vivax, Croatia) was 0-5000g so we created a platform weighing 4500g in total to maximally reduce the possibility of the platform to move during the testing procedure and to make sure the negative force resulting from rat holding onto the cage lid while being removed by the experimenter remains in the range of maximal quantification. In the proof-of-concept experiment boxes filled with old histological slides were found to be the most suitable weight. Duct tape is used to cover part of the cage lid grid the rat is not supposed to hold onto, and the whole cage is placed on the PASTA platform and additionally secured by reusable putty-like pressure-sensitive adhesive (Patafix, UHU, Germany). When the platform is ready the PASTAgp script is loaded. Once the ID of the animal is provided, a pyqtgraph real-time plot of the scale-extracted data is initiated and PASTA platform is calibrated by pressing the reset button on the microcontroller ("EN" for NodeMCU ESP-32S). The animal is placed on the exposed part of the cage lid and gently vertically elevated by the tail. The animal will resist being removed and negative force will be recorded by the platform. We repeated the procedure 5 times. Once the trial is finished, real-time plot is closed and the data is automatically saved in the .pasta file in the working directory. An example of a single trial of 5 consecutive measurements was imported into R and visualized with ggplot (**Fig 1D**). An example of a single measurement from the trial is shown in **Fig 1E**. A video example of a single measurement is provided in **Supplement 1**.

Additional technical and conceptual considerations

The end user should pay attention to several technical details for optimal adaptation of the griPASTA platform for specific experimental purposes. The rodent cage used as a grip test platform should be carefully chosen based on what the experimenter wants to examine. For our proof-of-concept purposes, we found the 2184L Eurostandard Type II L cage with dimensions of 365x207x140 mm to be the best fit as the grid arrangement was optimal for the forelimb grip in rats and enabled reduction in grip variability between subjects once the duct tape was placed on lateral side of the cage lid. Nevertheless, high inter-individual variation has been recognized in the literature as one of the main challenges of the rodent grip strength test so special attention should be directed to adequate habituation and handling of experimental animals as well as training of the experimenter. Moreover, a suitable number of measurements for each animal should be chosen. In this study we demonstrated how to use the rodent cage and the lid as the grip platform, however, both the platform and the position of the load cells can be modified. Takeshita et al. demonstrated that the grip strength test can be modified by changing the position of the platform[6]. This affects the proportion of forces that contribute to the net force measured by the test. Additionally, modification of the platform position affects the motivation of the rodent to keep gripping the bar recognized as a major source of inconsistency in the classic grip strength test [6,10]. The griPASTA platform position

can be modified by either changing the position of the platform or introducing an additional platform with a pulley (**Fig 1F**). Also, even though the whole concept of griPASTA is based on a modified kitchen scale, cheap strain gauge load cells that are readily available over the internet are compatible with griPASTA and some of them might be easier to implement in specific platform designs in comparison with the ones found in most kitchen scales. For this reason we suggest researchers interested in modified grip strength platforms to investigate the available options when considering the new design (**Fig 1G**). Finally, a word of caution. The concept of grip strength measurement in rodents has been extensively used and its (many) limitations are well known. For example, some authors suggest the test should be called a grip performance test instead to emphasize numerous confounding factors universally present in similar behavioral experiments[10]. griPASTA is a simple tool with numerous possibilities, however interpretation of its data, just like the data obtained from the commercially available grip strength tests can be challenging so users are encouraged to study the conceptual background of the test attentively prior to implementation in the routine research practice.

Conclusion

griPASTA is a simple open-source PASTA-based[8] solution for grip strength assessment in rodents that can be made on the cheap using readily available utensils. The whole setup consists of a hacked kitchen scale connected to a computer and a mouse cage used as a grip platform. Apart from the cost, griPASTA provides several advantages over the commercially available solutions as the platform provides raw data which makes it compatible with different data analysis strategies and its flexible design makes it highly customizable.

Data and code availability statement

A general purpose python script for extraction of data from the PASTA platform (PASTAgp) is available on GitHub at: https://github.com/davorvr/pasta-gp
Data from the proof-of-concept experimental trial (ID.pasta) and a video example of a single measurement trial are available on GitHub at: https://github.com/janhomolak/gripasta

Ethics committee approval

All experiments were conducted following the highest standards of animal welfare and only certified personnel handled animals. Animal procedures were carried out at the University of Zagreb Medical School (Zagreb, Croatia) and were in compliance with current institutional, national (The Animal Protection Act, NN135/2006; NN 47/2011), and international (Directive 2010/63/EU) guidelines governing the use of

experimental animals. The experiments were approved by the Ethical Committee of the University of Zagreb School of Medicine and the Croatian Ministry of Agriculture (229/2019).

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Conflict of interest

None.

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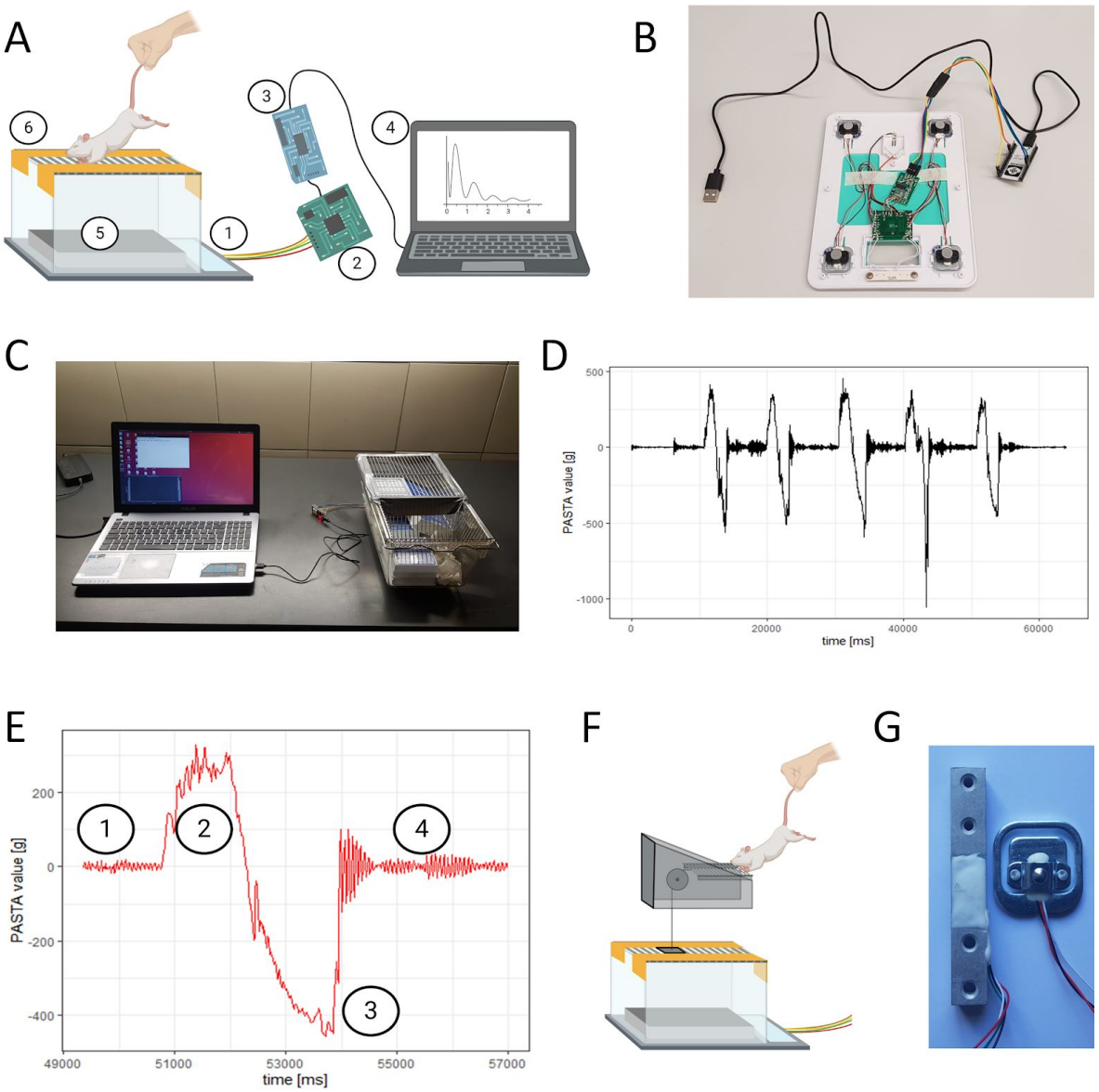

Fig 1. Concept of griPASTA. **A)** A Schematic representation of griPASTA setup for grip strength performance measurements in rodents. A1 - PASTA: modified kitchen scale described by Virag et al.[8]; A2 - HX711 circuit board; A3 - NodeMCU ESP-32S microcontroller; A4 - laptop; A5 - a weight stabilizing the mouse cage; A6 - Duct tape modified cage lid used as a grip platform. **B)** PASTA setup. A NodeMCU ESP-32S microcontroller interfaced with kitchen scale strain gauge load cells through the HX711 circuit board. **C)** A Photograph of griPASTA setup with a grip test platform fixed on top of the PASTA platform. **D)** Raw data from a single trial with 5 consecutive measurements. **E)** An example of raw data from a single measurement. E1 - baseline data; E2 - positive deflection caused by placement of the animal on top of the platform (positive deflection indicates weight of the animal); E3 - negative deflection caused by animal holding onto the platform while being removed by the tail. Minimal value is the peak force the animal was able to resist; E4 - baseline values with noise recorded due to placement of the animal on the table next to

griPASTA. In general, commercial instruments measure maximal force the animal is able to resist which corresponds to the maximal negative deflection value (E3) in the griPASTA plot. In other words, greater negative deflection, stronger the grip of the animal. Other parts of the plot are also informative and they should be interpreted based on what the experimenter wanted to examine and how. In the standard protocol, the area under the curve (E3) normalized for baseline (E1) can provide useful information on the strength endurance as greater area indicates the animal was able to resist a specific force for a specific period of time. **F)** A schematic representation of one example how the grip platform can be modified with a pulley. **G)** Different designs of the load cells that can be with various designs of griPASTA.