

FlexiKnee Pro

02

Interactive Wearable Design
Personal Project

2024.10.11

FlexiKnee Pro is a smart wearable knee brace designed for construction workers, combining advanced materials, ergonomic design, and smart technology to enhance comfort and safety. Made with waterproof and stretchable fabrics, it features elastic straps and a spring-loaded hinge system for a secure and flexible fit, while an adjustment dial allows tension customization. A built-in flexion sensor tracks knee movements, transmitting data via a chip to a connected device for real-time monitoring. The app, with a sleek black, blue, and purple interface, displays key metrics such as time, heart rate, daily knee bends, and total knee bends. A light-indicator strip on the brace provides strain feedback, alerting users to overuse and helping prevent injury. FlexiKnee Pro offers a perfect blend of functionality, durability, and style for high-performance work environments.

Research

// Inspiration

FlexiKnee Pro was inspired by the challenges **construction workers** face, with long hours and intense physical demands often leading to knee injuries. The design combines wearable technology and ergonomic support to promote proactive **knee health**, offering **protection, real-time monitoring, and comfort** for demanding work environments.



// Primary Research

The research focused on six common knee conditions, including Prepatellar Bursitis, Meniscus Injury, Patellofemoral Pain Syndrome, Knee Osteoarthritis, Patellar Tendonitis, and Ligament Damage. These insights helped identify key requirements for protection, monitoring, and support in knee health solutions.

Effects of overuse of the knee



Prepatellar Bursitis

This condition involves inflammation of the bursa located in front of the kneecap. It is commonly caused by prolonged kneeling, direct trauma, or repetitive movements, leading to swelling, tenderness, and discomfort.



Meniscus Injury

A tear or damage to the cartilage that cushions the knee joint, often caused by twisting, heavy impact, or sudden movements. It can result in pain, swelling, and difficulty bending or straightening the knee.



Patellofemoral Pain Syndrome

A common issue characterized by pain around or behind the kneecap, typically due to overuse, improper alignment, or weak thigh muscles. It is often exacerbated by activities like running, squatting, or climbing stairs.



Knee Osteoarthritis

A degenerative condition where the cartilage in the knee joint gradually wears down, leading to pain, stiffness, swelling, and reduced joint flexibility. It is more common in older adults or individuals with previous knee injuries.



Patellar Tendonitis

Also known as jumper's knee, this condition involves inflammation or irritation of the tendon connecting the kneecap to the shinbone. It is often caused by repetitive stress from jumping, running, or other high-impact activities.



Ligament Damage

Injuries to the knee ligaments, such as the ACL or MCL, often occurring during sports or high-impact activities. These injuries can cause pain, swelling, instability, and reduced knee mobility.

Rebar Worker

Responsible for the processing, tying, installation, and welding of rebar, ensuring that the rebar structure meets design requirements.

Mason

Responsible for the construction of brick walls and concrete structures, as well as the preparation of cement and mortar for foundational construction work.

// Usage Scenario



Building Worker Knee Change

Principle



A series of effects occur as a result of the decrease in lubricant molecules in the knee joint, which decrease as the knee is used more.

Scaffolder

Responsible for the erection, dismantling, and safety inspection of scaffolding to ensure the safety of workers during high-altitude operations.

Plasterer

Responsible for smoothing and leveling work on walls, floors, and ceilings, ensuring the surfaces are even and smooth.

Affect

walk	stand
jog	squat

Market Research

// Primary Research

Existing knee support products, such as the Westinghouse KA3, HKA Knee Massager, and SKG W3 Series, focus on heat therapy, compression, and customizable settings. While effective for pain relief, they often struggle with bulkiness, energy demands, and limited adaptability, providing key opportunities for FlexiKnee Pro to offer a more user-friendly and efficient solution.



Westinghouse Knee Massager KA3



HKA Knee Massager



SKG Smart Knee Massager W3 Series 2nd Generation

Product Info

Description

This massager combines airbag compression, vibration massage, and heat therapy. It features three massage modes, five heat settings, and three levels of airbag compression, allowing users to customize their experience.

Offering three heat settings with a maximum temperature of 65°C, this massager provides significant warmth to the knee area.

This device offers comprehensive knee care through four-zone massage, encompassing the entire knee area.

Strengths & Weaknesses

- Strengths**
- The device provides four-zone massage, targeting the entire knee area.
 - The X-shaped support ring around the patella offers additional stability.

- Weaknesses**
- The device might be bulky or heavy, possibly limiting portability or comfort during prolonged use.
 - Limiting its usability for a broader range of body types.

- Strengths**
- Users can personalize their heat level.
 - Making the device especially beneficial for individuals with chronic knee issues.

- Weaknesses**
- May cause discomfort or even overheating for sensitive users if not carefully monitored.
 - May have high power requirements, potentially limiting usage time.

- Strengths**
- Users can personalize their experience for targeted pain relief and relaxation.
 - Improving blood flow and alleviating discomfort effectively.

- Weaknesses**
- Potentially requiring time to learn and adjust the settings for optimal use.
 - May have high energy demands.

User Research

Do you often experience knee pain?



Name: Zhang
Age: 48
Role: Mason
Working age: 28

Sometimes when work is intense

Yes, especially before it rains or when work is intense. My knees sometimes ache, and they can even feel stiff at times.

Do you do anything to prevent or ease the pressure on your knees?



Name: Yang
Age: 28
Role: Plasterer
Working age: 12

Try not to squat for long time

I try not to squat for too long and stand up to move around whenever I can. Sometimes, I also take a hot bath after work to relax.

Summary

Warning

+
Protect

+
Pain Relief



The user's knee can react to weather changes and intense work, highlighting the impact of external factors and workload on their condition. While short-term relief methods like moving around and hot baths show health awareness, they lack long-term solutions. This suggests opportunities for tailored support systems and enhanced pain relief products.

Concept

// Target Group



Construction workers who face frequent knee strain and require durable

// Design Goals

// Design Opportunity

To create a knee brace that combines comfort, real-time monitoring, and proactive knee protection through ergonomic design, smart technology, and durable materials, ensuring safety and usability in tough work environments.

FlexKnee Pro emphasizes real-time warnings to prevent injuries, data tracking for monitoring knee strain, and health guidance with personalized recommendations to promote long-term knee care.

Survey Question #1
Construction Workforce Number

58%

40-45% in China

I investigated the comparison between the number of construction workers in China and the United States. China overwhelmingly surpasses the U.S. in terms of numbers, a result of its rapid urbanization process.

Survey Question #2
Age distribution of Construction Worker in China

>90%

Research shows that 90% of construction workers are over 40, reflecting an aging workforce trend. Younger people are less inclined to join due to the demanding nature of the job, posing challenges to labor supply in the industry.

// main function



Alert



Tracking

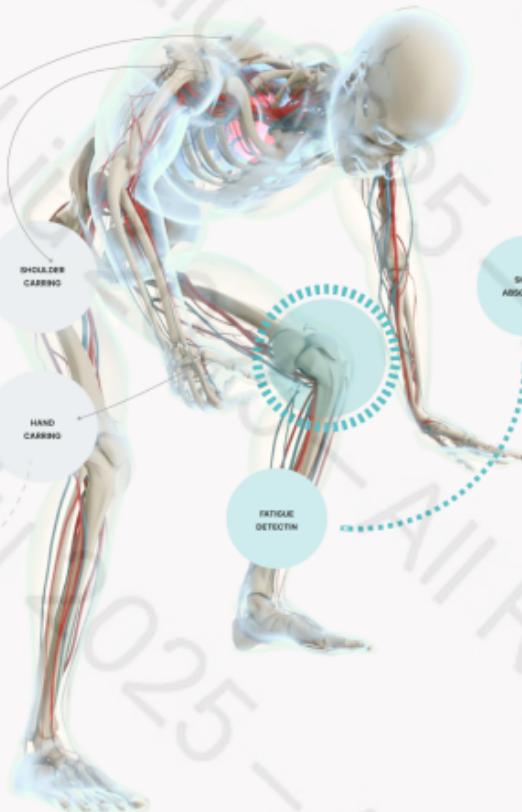


Guidance

System Map

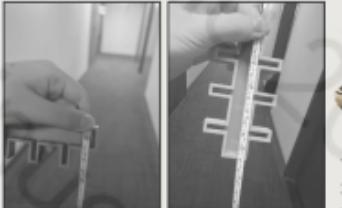
PRODUCT FUNCTION

// Inspiration





// Molding

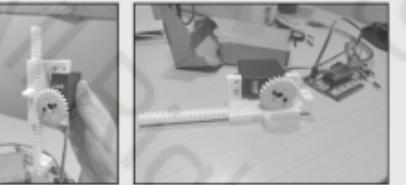


Design Process

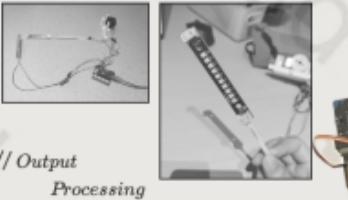
The process began with 3D modeling, followed by 3D printing a mold. I then prepared the silicone mixture and carefully poured it into the printed container. After letting it cure for several days, the silicone casing was successfully demolded, completing the process.



// Bending Visualization



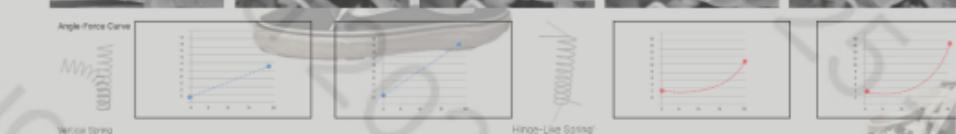
Considering the convenience of wearability, I replaced the servo gears with an RGB LED strip and mapped the bending degree to different light display types.



// Output Processing



// Spring Test



Angle-Force Curve Differences

Vertical Springs Angle-Force Curve:

- In a vertical spring, while displacement is linear (proportional to compression or stretching), if angular changes are involved with the spring's twisting part, the curve typically shows a linear increase in force as displacement increases, until the spring reaches maximum elastic limit.
- In this case, the Angle-Force Curve is usually similar and smoother.

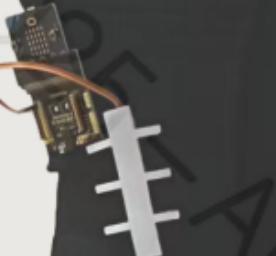
Hinge-Like Springs Angle-Force Curve:

- In a hinge-like spring, the Angle-Force Curve exhibits non-linear characteristics. As the angle increases, the rebound force gradually increases or changes, and at larger angles, the force may change more sharply.
- The curve may show significant inflection points or non-linear fluctuations, especially when the spring undergoes substantial torsion, causing a greater increase in force.



I created a bending sensor using silicone and attached it to a knee pad. To simulate a construction worker's day, I went through a process from standing to bending, taking photos at different stages and recording the sensor data.

This tracked knee angle and pressure changes during various activities, providing insights into knee strain. The data, combined with the photos, helps assess the knee pad's performance in real-world scenarios and identify areas for improvement in comfort, safety, and design.



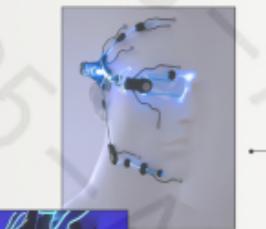
Prototyping

// Inspiration



Wearable

Designed with portability and user comfort in mind, it ensures durability and adaptability for everyday use in fashion and technology.

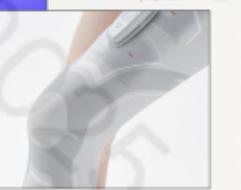


// Sketch



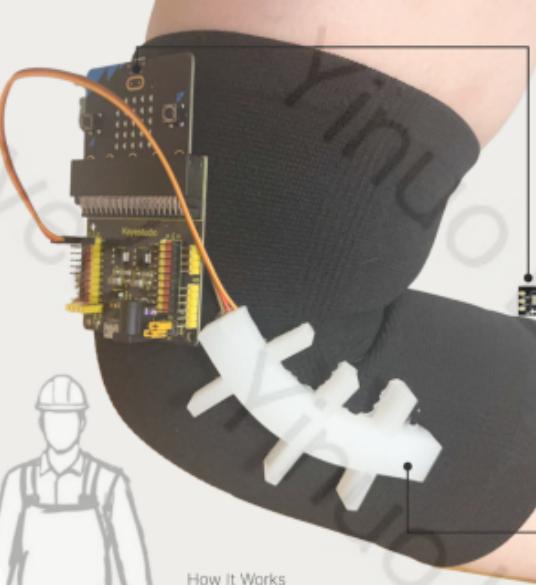
Luminous

It incorporates advanced light-emitting components, enabling dynamic illumination for aesthetic or functional purposes.



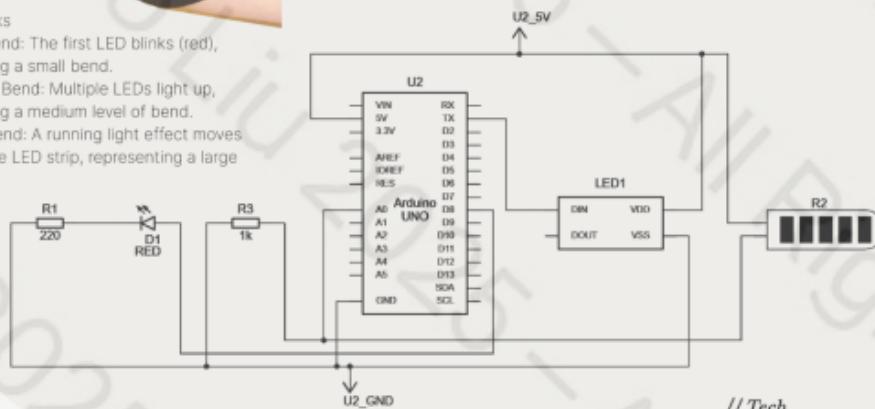
Skin-adhering

This technology involves ultra-thin, flexible materials that comfortably attach to the skin, allowing for seamless integration with the human body.



How It Works

1. Small Bend: The first LED blinks (red), indicating a small bend.
2. Medium Bend: Multiple LEDs light up, indicating a medium level of bend.
3. Large Bend: A running light effect moves along the LED strip, representing a large bend.



// Tech Design

